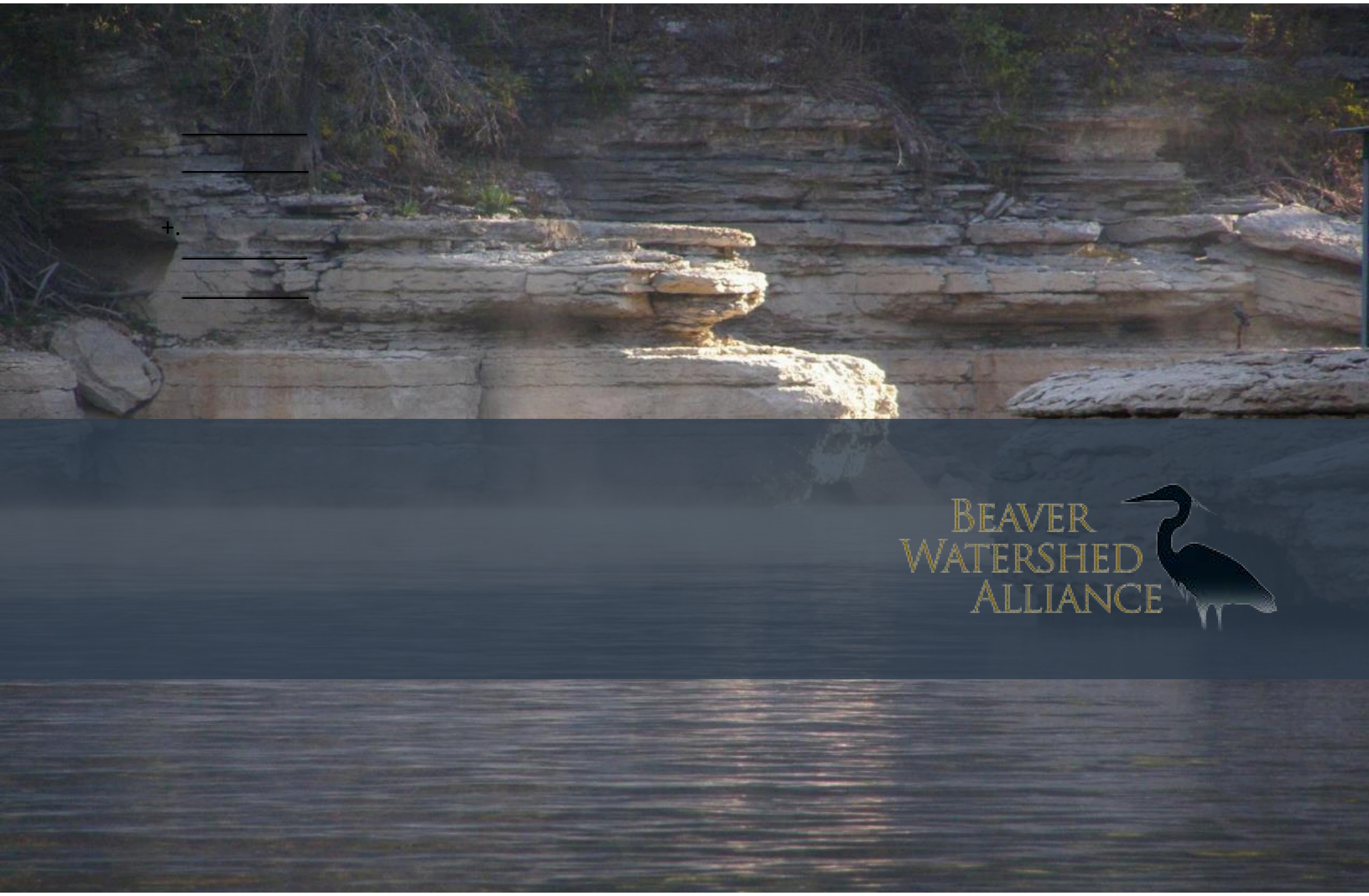

Beaver Lake Watershed Protection Strategy

2025 Revision

Prepared for:
Beaver Watershed Alliance

Prepared by:
RTI International (Modeling) with Contributions

2025 Revision

Beaver Lake Watershed Protection Strategy

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Executive Summary
Navigating Overlaps: Coexisting Management Plans

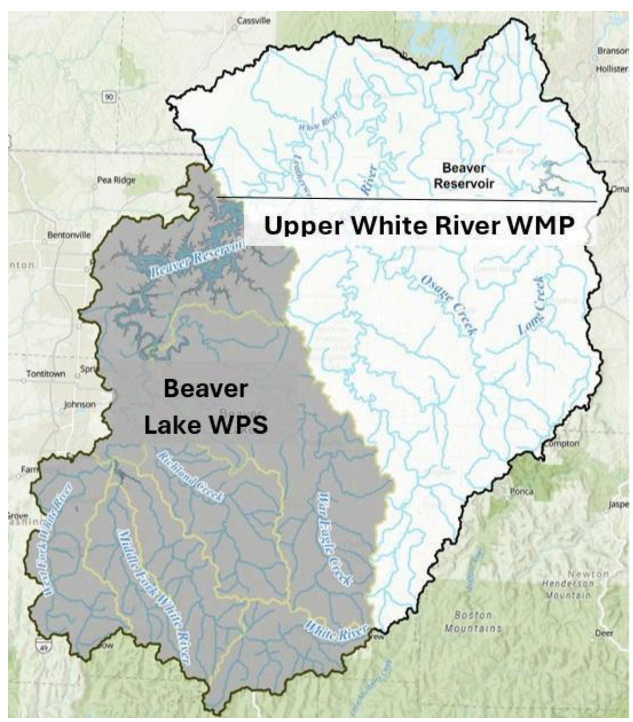
Two watershed plans were developed for the White River watershed in Northwest Arkansas during 2021-2025. The Beaver Lake Watershed Protection Strategy (WPS), developed by the Beaver Watershed Alliance, addresses the watershed that feeds into Beaver Lake, including streams such as West Fork White River, Middle Fork White River, White River, and War Eagle Creek. The Upper White River Watershed Management Plan (WMP), developed by H2Ozarks, addresses the watershed that feeds into Beaver Lake plus areas in Arkansas that eventually drain to Table Rock Lake, e.g., White River downstream of Beaver Lake, Kings River, and Long Creek.

Both plans address the Environmental Protection Agency's (EPA) 9-elements framework for comprehensive watershed management. By focusing on the EPA 9-elements, these plans strive to comprehensively address key aspects essential for effective watershed management. This includes:

1) Identification of Causes and Sources of Impairment;
2) Expected Load Reductions;
3) Proposed Management Measures;
4) Technical Assistance;
5) Information, Education and Public Participation;
6) Schedule;
7) Milestones;
8) Load Reduction Evaluation Criteria; and
9) Monitoring Component for Adaptive Management

"Together, these two plans provide a comprehensive approach to watershed management, recognizing the diverse needs and challenges of distinct geographic areas while upholding a unified commitment to environmental stewardship."

"Although both plans adhere to the EPA's 9-element framework, differences stem from variations in geographic focus, modeling methodologies, and organizational priorities (see table on next page). Despite these differences, both plans identify similar issues and concerns, and recommend many of the same practices to address them."



Plan Aspect	Upper White River WMP	Beaver Lake WPS
Geographic Focus	Entire Upper White River Watershed in Arkansas; larger area; more forest/pastureland	Only the Beaver Lake Watershed; smaller, more developed area; higher population density
Priority Areas	Based on presence of impaired waters, five identified water quality issues and threats, and modeled pollutant yields	Based on modeled pollutant yields, flood events, riparian pasture extent, and streambank erosion severity for current and future conditions
Modeling Approach	Models current conditions using SWAT model at HUC12 scale	Models current and future conditions using WaterFALL model at catchment scale
Water Quality Focus	All waterbodies support designated uses	Waterbodies support designated uses with emphasis on Beaver Lake water supply use

The most obvious difference between the two plans is the geographic area of focus. Because of its smaller area, the Beaver Lake watershed has a higher percentage of developed area and a higher overall population density than the Upper White River watershed. The Upper White River watershed has slightly higher percentages of forest and pastureland. The differences in geographic areas addressed by these plans contribute to differences in the management priorities of the lead organizations.

One of the differences between the plans is the identification of priority areas for implementation of management measures (part of element #3 above). The WPS identified separate priority areas for management of upland areas (based on watershed modeling results, flow characteristics, and streamside land use) and for streambank restoration (based on field surveys and other information). The WMP identified one set of subwatersheds that are recommended for further implementation of management measures. The WMP prioritization was based on water quality impairments, watershed modeling results for sediment and nutrients, and risks of various water quality impacts determined by the Natural Resources Conservation Service.

The watershed modeling for each plan was developed with different modeling software that utilizes different algorithms and assumptions. Because both models used some of the same input information (including rainfall, land use, and point source discharge data) and were calibrated to observe water quality data, there were some general similarities in spatial patterns of results between the two models. Both current and future conditions were modeled in the WPS, but only current conditions were modeled in the WMP.

Together, these two plans provide a comprehensive approach to watershed management in the White River watershed in Northwest Arkansas, recognizing the diverse needs and challenges of distinct geographic areas while upholding a unified commitment to environmental stewardship.

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Acronyms and Abbreviations

ADH	Arkansas Department of Health
AEU	Animal Equivalent Unit
AHTD	Arkansas Highway and Transportation Department (now Arkansas Department of Transportation)
Alliance	Beaver Watershed Alliance
ANRD	Arkansas Department of Agriculture – Natural Resources Division
APC&EC	Arkansas Pollution Control and Ecology Commission
ARDOT	Arkansas Department of Transportation
AWRC	Arkansas Water Resource Center
BMPs	Best Management Practices
BWRPWA	Benton Washington Regional Public Water Authority
CREP	Conservation Reserve Enhancement Program
DEM	Digital Elevation Model
DISTRICT	Beaver Water District
DEQ	Arkansas Department of Energy and Environment – Division of Environmental Quality
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
GI	Green Infrastructure
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies (part of NASA)
ICLUS	Integrated Climate and Land Use Scenarios (ICLUS)
IPCC	Intergovernmental Panel on Climate Change’s
LID	Low Impact Development
LULC	Land Use/Land Cover
MCRWD	Madison County Regional Water District
MFWR	Middle Fork of the White River
MS4	Municipal Separate Storm Sewer Systems
NCD	Natural Channel Design
NED	National Economic Development
NGOs	Non-governmental organization
NHDPlus	National Hydrography Dataset
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSE	Nash-Sutcliffe Efficiency
NTU	Nephelometric Turbidity Unit
NWA Council	Northwest Arkansas Council
NWALT	Northwest Arkansas Land Trust

OWW	Ozark Water Watch (now H2Ozarks)
PAG	Policy Advisory Group
PBIAS	Percent bias
PLET	Pollutant Load Estimation Tool
POTW	Publicly Owned Treatment Works
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCP	Representative Concentration Pathway
RCPP	Regional Conservation Partnership Program
RTI	Research Triangle Institute International
SCADA	Supervisory Control and Data Acquisition
SPA	Source Protection Area
SSP	Shared Socioeconomic Pathway
Strategy	Beaver Lake Watershed Protection Strategy
SWAT	Soil & Water Assessment Tool
SWPP	Storm Water Pollution Prevention Plan
TAG	Technical Advisory Group
TC	Technical Committee
TDR	Transfer of Developments Rights
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WaterFALL	Watershed Flow and Allocation Model
WCRC	Watershed Conservation Resource Center
WEPP	Watershed Erosion Prediction Project
WFWR	West Fork of the White River
WQS	Water Quality Standard
WWTP	Wastewater Treatment Plant

1 Introduction

To proactively address the potential for problems and protect water quality within the lands and waters upstream of Beaver Lake, Arkansas, the Beaver Watershed Alliance (Alliance) has adopted the 2023 Beaver Lake Watershed Protection Strategy (Strategy) update. This Strategy builds upon two previous efforts from 2009 and 2012, which set forth the original and 2012 update of the Strategy. The overarching goals, objectives, and guiding principles from the earlier Strategy remain unchanged, except for additional objectives added and documented below.

1. Overarching Goals

Three overarching goals were established as the result of discussion and consensus-building among a Policy Advisory Group (PAG), which was the stakeholder group that assisted in developing the management plan:

1. Maintain a long-term, high-quality drinking water supply to meet present needs and continuing growth of the region.
2. Restore water quality of impaired stream and lake areas (as listed on Arkansas Department of Energy and Environment – Division of Environmental Quality (DEQ)'s list of impaired waters).
3. Minimize additional costs and regulations for people living and working in the watershed.

One of the stated goals of the group was to utilize watershed protection strategies that were voluntary and did not impose additional regulations on landowners or municipalities. If water quality continues to degrade in the watershed, it was assumed that additional costs for drinking water treatment and potential regulatory compliance would exceed the preventative strategies recommended in this plan.

2. Objectives for Beaver Lake & Its Watershed

In pursuing the stated goals, the following objectives were specified:

- Minimize risks to public health and safety.
- Minimize taste, odor, and color problems in the public drinking water supplies.
- Minimize impact on water supply intakes and treatment operations.
- Meet long-term needs for water supply in the region.
- Maintain recreation enjoyment and ensure that recreation reflects environmentally sound stewardship of the lake.

- Restore water quality in impaired areas to meet water quality standards.
- Provide an economically priced water supply.

In addition to the previous objectives set forth in the earlier Strategy, the update adds the following objectives:

- Protect, restore, and sustainably manage water quality and ecological resources within the watershed.
- Measure results through Watershed Success Metrics.

3. Guiding Principles

Finally, to meet the goals and objectives, guiding principles were developed to ensure efficiency, effectiveness, completeness, and fairness in establishing the protection strategy:

- Success depends on a technical foundation and community support.
- Recommendations:
    - Address specific issues
    - Support diverse economy
    - Be cost-effective
    - Respect private property rights
- Implement primarily through:
    - Outreach and education
    - Stewardship and voluntary land management practices
    - Resource management
    - Compliance with existing regulations

1.1 Why Are These Protection Measures Needed?

Beaver Lake is the primary drinking water source for more than 550,000 Arkansans (1 in 5 Arkansans) and a major economic anchor for the region. As the principal water supply for Northwest Arkansas, the lake is recognized as a lifeline for current citizens and businesses, and for the projected growth of the region. People in Northwest Arkansas also enjoy the beauty of the lake and the abundant recreational opportunities it provides, including fishing, boating, hiking, camping, wildlife watching, swimming, and more. Beaver Lake is a key to the region's quality of life, and water quality of Beaver Lake and its inflows are important to the region.

The Arkansas Water Resources Center (AWRC) has been monitoring water quality of the major inflows (i.e., the larger subwatersheds used in the modeling efforts, RTI International, 2022) into Beaver Lake, northwest Arkansas (Figure 1-1). Funding for these water-quality projects has been provided by the Arkansas Department of Agriculture Natural Resources Division (ANRD) 319 Project and Beaver Water District (District). These water samples were collected following quality assurance project plans approved by ANRD and the Environmental Protection Agency (EPA), since 2009; all water-quality data are publicly available in EPA's Water Quality Portal (WQP). The water quality, constituent load estimates, and trends in flow-normalized concentrations are reported in detail by Grantz and Haggard (2023). The observed concentrations and flow-normalized trends in total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) are detailed below for select sites within the Beaver Lake Watershed to give context to the past and current water quality of the inflows.

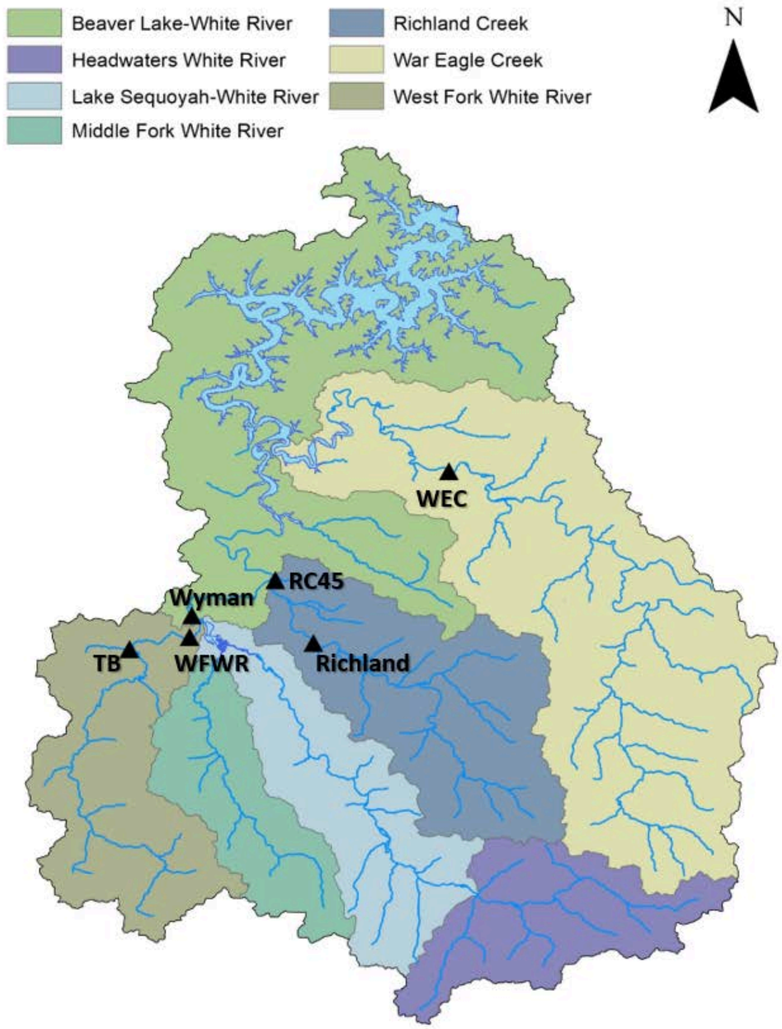


Figure 1-1. Sites Routinely Monitored for Water Quality by the Arkansas Water Resources Center (AWRC), including the White River (Wyman, USGS Site 07048600) , Richland Creek (RC45 and Richland, USGS Sites 07048800 and 07048780, respectively) and War Eagle Creek (WEC, USGS Site 07049000) (from Grantz and Haggard 2023).

The major input into Beaver Lake is the White River Watershed, and this site has historically been monitored at the White River near Fayetteville at Wyman Road Bridge (USGS Site 07048600), where the watershed is over 25,000 acres with a watershed that is mostly forested (73%, NLCD 2019) with pasturelands (18%, NLCD 2019) and urban development (8%, NLCD 2019) (Grantz and Haggard, 2023). The following graphs show observed concentrations over time, detailing the variability of observed TN, TP, and TSS over time, i.e. since 2009 (Figure 1-2, left side). The water-quality data and USGS mean daily streamflow were used in Weighted Regression on Time, Discharge, and Season (WRTDS, Hirsch et al., 2010; Sprague et al., 2011) to estimate “flow-normalized” concentrations over time (Figure 1-2, right side). WRTDS removes the influence of changes in measured discharge across the sampling dates, i.e. flow-normalizing, allowing the visualization of flow normalized concentrations over time to understand how water quality is changing over time. At the White River (Wyman, USGS Site 07048600), the following trends were observed in flow-normalized concentrations of TN, TP, and TSS:

- Flow-normalized TN concentrations show a strong seasonal pattern, no change in the mean and range from 2009 through 2015, and decreasing TN since 2015 (through 2022).
- Flow-normalized TP concentrations show a seasonal signature, no change in the mean and range from 2009 through 2015, and decreasing TP since 2015 (through 2022).
- Flow-normalized TSS concentrations show a seasonal signature and relatively little change over time, possibly a slight increase from 2009 through 2022.

Key Insights: Water quality (i.e., TN and TP) has been improving over time, at least since 2015. However, sediment (i.e., TSS) has not really changed much over time, and it may be trending upward ever so slightly. Thus, the directional change (i.e., decreasing TN and TP) is in the right direction, suggesting that adaptive watershed management has been effective since the 2012 Beaver Lake Watershed Protection Strategy. However, continued efforts are needed to reduce sediment inputs into Beaver Lake from the White River.

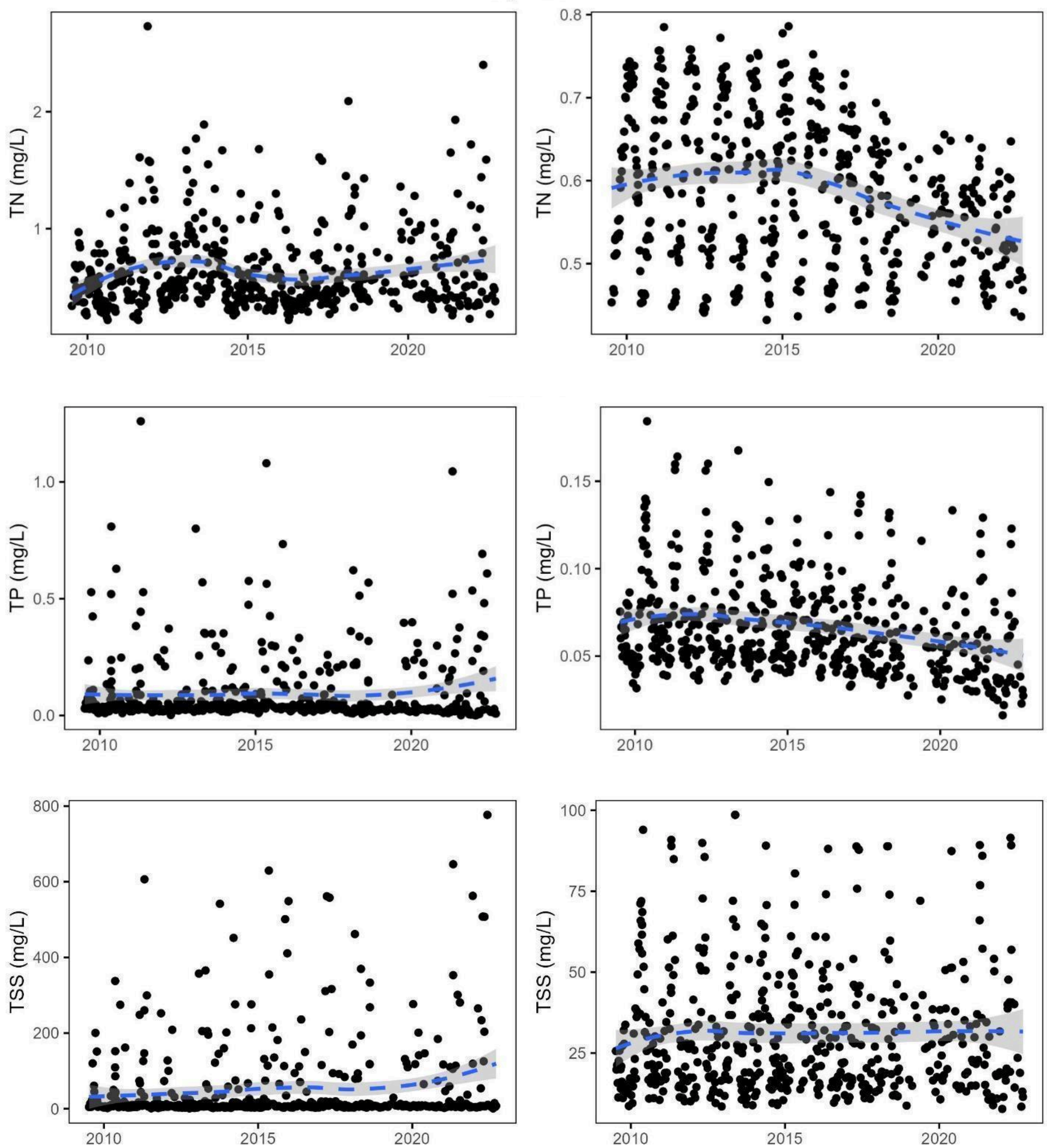


Figure 1-2. Observed Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) Concentrations at the White River (Wyman) near Fayetteville, Arkansas at Wyman Road Bridge (USGS Site 07048600) from the Arkansas Water Resources Center (AWRC) (left) and Flow-normalized Concentrations from Weighted Regression on Time, Discharge, and Season (WRTDS) Modeling on the Concentration and Discharge Relations over Time (More Details, See Grantz and Haggard, 2023); the Dashed Blue Lines Represent Changes over Time, and this

Section Focused on the Changes in Flow-normalized Concentrations over Time Providing Context to the Updated Watershed Protection Strategy (Dashed Blue Line, Right).

Richland Creek is another major inflow into Beaver Lake, and this river has historically been monitored at two different sites (Figure 1-1), including Richland Creek at Arkansas Highway 45 (RC45, USGS Site 07048800) from 2009 to 2014, and Richland Creek at Tuttle Road or County Road 79 bridge (USGS Site 07048780) 2015 to 2022. The USGS changed the location of the stream discharge gage in 2015 due to the proximity of RC45 (USGS Site 07048800) to Beaver Lake and backwater conditions making mean daily discharge estimation challenging. The AWRC shifted its monitoring station to the relocated stream discharge gage, and the Richland Creek Watershed at relocated gaging station is over 76,000 acres at this point, representing about 87% of the watershed area at the historic downstream site (i.e., RC45, USGS Site 07048800); the watershed at this point has approximately 66% forest, 29% pasturelands, and 5% urban development (based on 2019 NCLD). The following graphs focus on the site, Richland (USGS 07048780), showing observed concentrations over time, detailing the variability in observed TN, TP, and TSS over time, i.e. since 2015 (Figure 1-3, left side). The flow-normalized concentrations from WRTDS are also shown over the same period, allowing visualization of how flow-normalized concentrations are changing over time to understand how water quality is changing over time (Figure 1-3, right side). At Richland Creek (Richland, USGS 07048780), the following trends were observed in flow-normalized concentrations of TN, TP and TSS:

- Flow-normalized TN concentrations show a strong seasonal pattern, and flow-normalized TN concentrations have been decreasing since 2015 (through 2022).
- Flow-normalized TP concentrations were variable, showing that flow-normalized concentrations have decreased over time (2015 to 2022) but may have stabilized in more recent years.
- Flow-normalized TSS concentrations show variability over time, but no discernible change in TSS over time.

Key Insights: Water quality (i.e., TN and TP) has been improving over time, since 2015. However, sediment (i.e., TSS) has not really changed much. The directional change (i.e., decreasing TN and TP) is in the right direction, suggesting that adaptive watershed management has been effective since the 2012 Beaver Lake Watershed Protection Strategy. However, sediment inputs into Beaver Lake from the Richland Creek watershed have not changed over time.

Looking at the historic site (RC45, USGS 07048800, data not shown), flow-normalized TN and TP told a little different story, showing that nutrients were increasing over time (i.e., 2009 to 2015 when monitoring shifted to Richland, USGS 07048780). Flow-normalized TSS were not really changing over time at RC45 (USGS 07048800) like the upstream Richland (USGS Site 07048780). This might suggest that nutrient sources further downstream might be a concern in the Richland Creek Watershed, but data is lacking to understand recent changes in water quality.

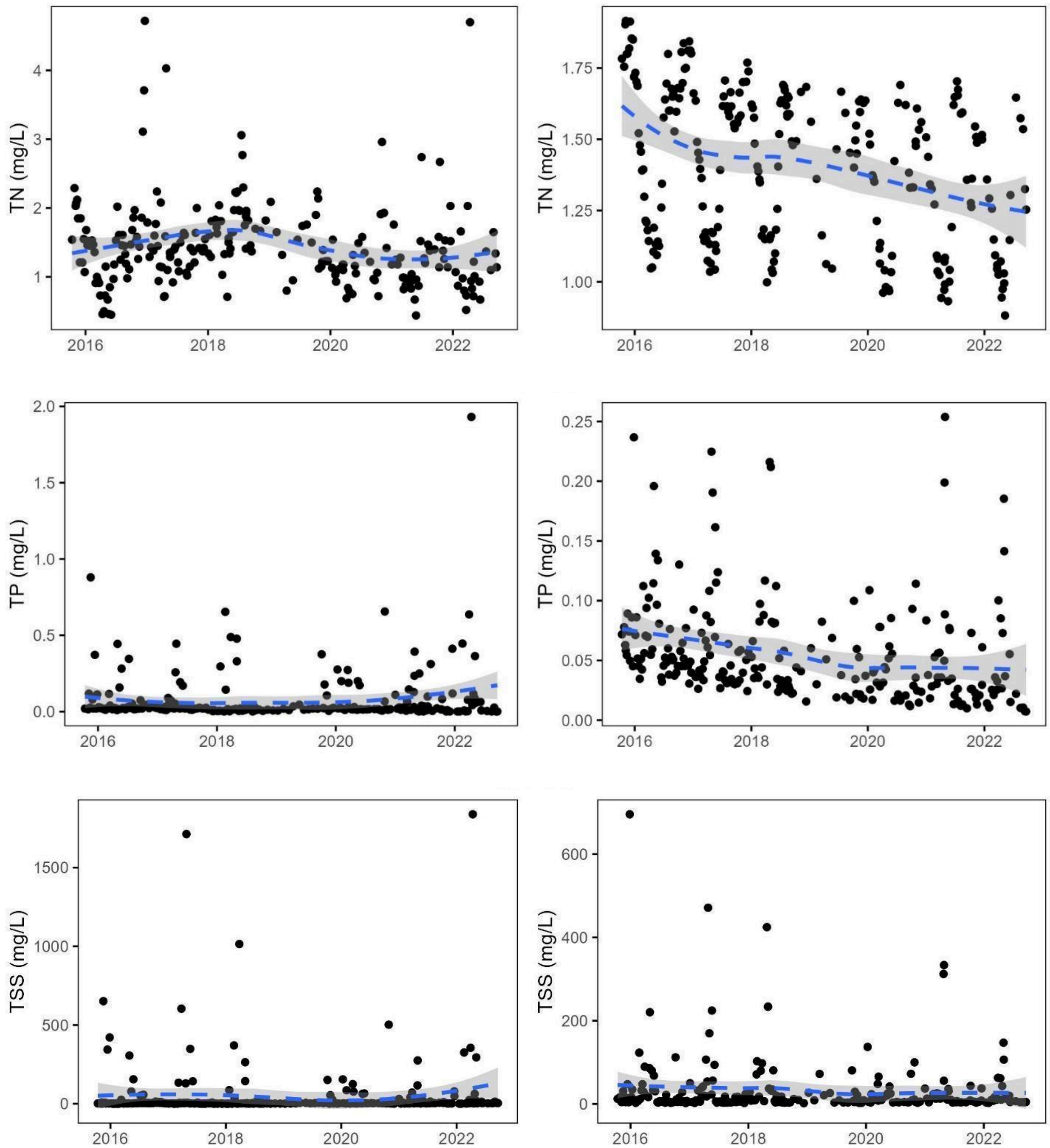


Figure 1-3. Observed Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) Concentrations at the Richland Creek (Richland) at Tuttle Road or County Road 79, Arkansas (USGS Site 07048780) from the Arkansas Water Resources Center (AWRC) (left) and Flow-normalized Concentrations from Weighted Regression on Time, Discharge, and Season

(WRTDS) Modeling on the Concentration and Discharge Relations over Time (More Details, See Grantz and Haggard, 2023); the Dashed Blue Lines Represent Changes over Time, and this Section Focused on the Changes in Flow-normalized Concentrations over Time Providing Context to the Updated Watershed Protection Strategy (Dashed Blue Line, Right).

The War Eagle Creek watershed is another major inflow into Beaver Lake, and this site has historically been monitored at War Eagle Creek at Arkansas Highway 45 and just downstream at Arkansas Highway 303 (WEC, USGS 07049000). At this point along War Eagle Creek, the watershed is almost 17,000 acres with 59% forest, 35% pasturelands, and less than 6% urban development. The following graphs show observed concentrations over time, detailing the variable nature in observed TN, TP, and TSS over time and especially with discharge (Figure 1-4, left side). The flow-normalized concentrations are shown on the right side of Figure 1-4, allowing visualization of how water quality has changed over time, i.e. since 2009. At War Eagle Creek (WEC, USGS Site 07049000), the following trends were observed in flow-normalized concentrations of TN, TP, and TSS:

- Flow-normalized TN concentrations show a strong seasonal pattern, an increasing range over time, and flow-normalized TN concentrations were relatively stable early in the study period but have been increasing since 2014 (through 2022).
- Flow-normalized TP concentrations were variable, showing that flow-normalized concentrations have decreased over time (2009 to 2022).
- Flow-normalized TSS concentrations show variability over time, but no discernible change in TSS over time.

Key Insights: Water quality shows a mixed response, where TP has been decreasing and TN has been increasing over recent time. Sediment at War Eagle Creek (WEC, USGS Site 0704900) on the other hand shows a response not different than the other major inflows, where TSS concentrations are not really changing. The directional change in TP is exciting (i.e., decreasing flow-normalized TP concentrations), while the directional change in flow-normalized TN concentrations is concerning. This suggests that nutrient sources, especially N sources in the landscape, should be a focus of future revisions to the 2012 Beaver Lake Watershed Protection Strategy, and there is work left to do in the future to address the sediment inputs into Beaver Lake.

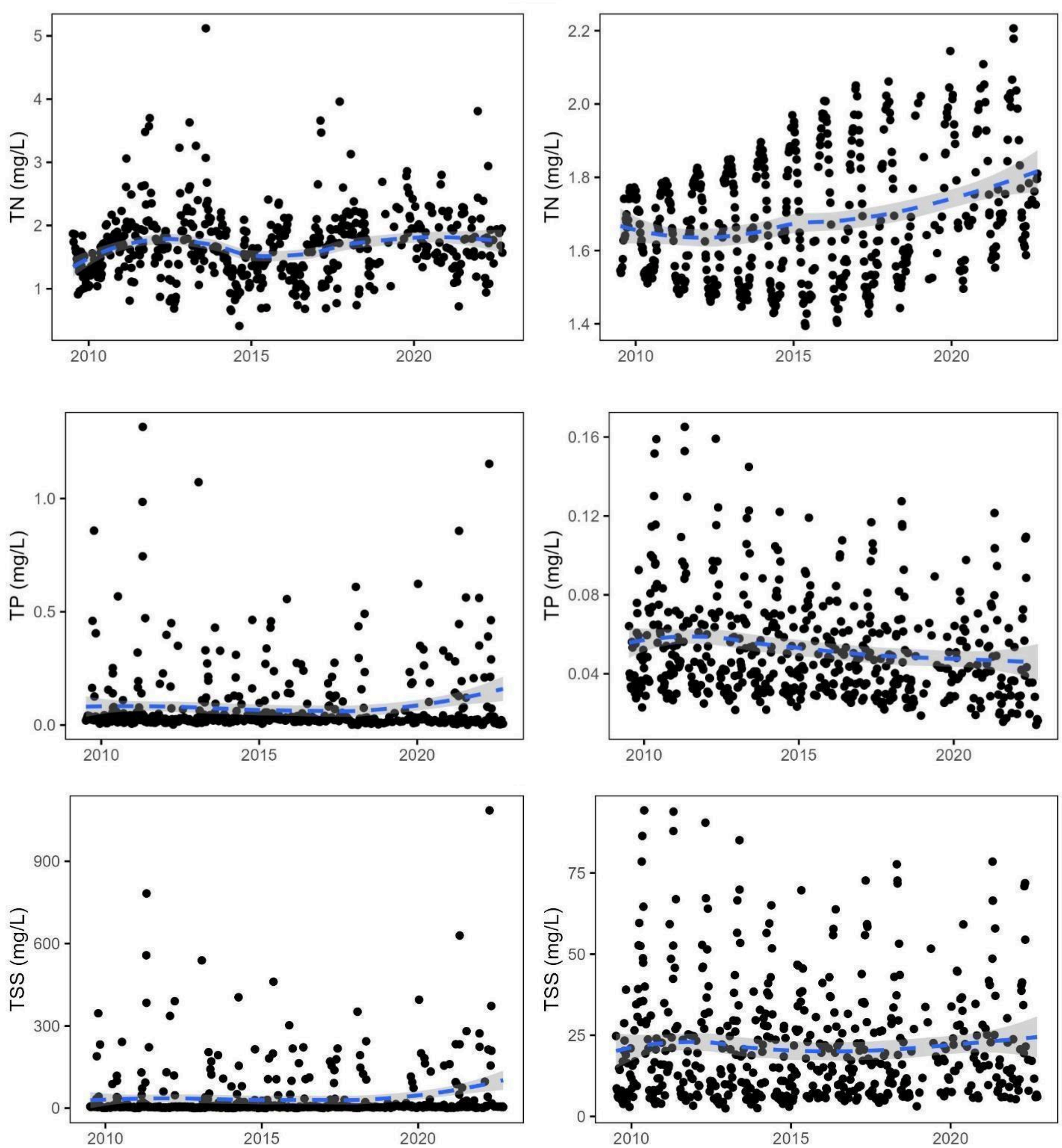


Figure 1-4. Observed Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) Concentrations at the War Eagle Creek (WEC), Arkansas (USGS Site 07049000) from the Arkansas Water Resources Center (AWRC) (left), and Flow-normalized Concentrations from Weighted Regression on Time, Discharge, and Season (WRTDS) Modeling on the Concentration and Discharge Relations over Time (More Details, See Grantz and Haggard, 2023); the Dashed Blue Lines Represent Changes over Time, and this Section Focused on the Changes in

Flow-normalized Concentrations over Time Providing Context to the Updated Watershed Protection Strategy (Dashed Blue Line, Right).

In addition to water-quality data and directional change noted, the U.S. Army Corps of Engineers (USACE) produces a biennial report, “Value to the Nation - Fast Facts” (US Army Corps of Engineers, Institute for Water Resources, 2019), which summarizes the social, economic, and environmental benefits USACE lakes provide for all Americans. According to the 2019 report, approximately 3 million visitors spend about $101 million annually within 30 miles surrounding Beaver Lake, with about $91 million of that captured in the local economy. The spending generates 1,058 jobs and provides approximately $52 million in added value, with $34 million in National Economic Development (NED) benefits.

In 2013 and 2017, the Beaver Watershed Alliance commissioned Opinion Research Associates Inc. to conduct a public opinion poll, where 400 heads of household were interviewed in Benton, Madison, and Washington Counties in Arkansas. The most common use of Beaver Lake is for drinking water, indicated by 87% of respondents. In Washington County, 90% said they use it for drinking water, in Benton County 84% said they use it for drinking water, and in Madison County 75% use it for drinking water. There was 99% agreement that “Beaver Lake is important to me and my family,” and 57% of respondents agreed with the statement that “water quality in Beaver Lake is endangered.” Nearly 73% of respondents agreed that preventing pollution is less expensive than the cost of treating polluted water.

People appreciate that most areas of Beaver Lake are clean most of the year. However, the upper end of the lake is impacted by sediment and algae. This in turn affects drinking water quality, recreation, and aquatic habitat in the upper lake. For example, customers of the Beaver Water District (the District) regularly experience taste and odor problems in their water in September and October (and occasionally during other months of high algal production). Without responsible water quality protection measures, the projected growth and development in the watershed will likely worsen this and other problems.

Projected growth could also cause economic impacts. While the future is uncertain, projections of future climate and land use changes are available through a variety of models and sources. A study with the District titled *Conservation Assessment of Beaver Lake Watershed* (RTI International, 2022) included an examination of future land use changes due to projected population growth and a series of projected climate scenarios. The results of this study point to a large range of potential changes in the quality and quantity of water reaching Beaver Lake. Climate models generally agree that this region of the country will experience a wetter and warmer climate (discussed further in Section 2.1.3). With land development trends and a wetter climate, there is the potential for:

- Up to a doubling of the annual sediment load delivered to the lake due to an increased frequency of high flow events delivering land-derived sediment loads as well as increased rates of streambank erosion.
- Up to a 64% increase in nitrogen loads and 23% increase in phosphorus loads reaching Beaver Lake on average each year through the main tributaries. These potential load increases are highly dependent on the future increases in precipitation as large storm events with less influence from land development, which is projected to continue along the western boundary of the watershed and in the conversion of pasture lands in pockets throughout the watershed to residential areas.
- Negative impacts to the lake's local tourism and recreation industry including revenue, jobs, and income with neglected water quality measures.

The *Conservation Assessment of Beaver Lake Watershed* (RTI International, 2022) shows land restoration in the form of converting riparian pasture lands back to native vegetation such as oak savannah or prairie habitats can reduce the negative effects of land development and climate change, although some increase in loadings of sediments and nutrients is expected to occur without large-scale action throughout the watershed.

1.2 How Were the Previous Lake Protection Strategies Developed?

The Northwest Arkansas Council (NWA Council) contracted with Tetra Tech to develop the first Strategy in 2009. Tetra Tech worked closely with a 23-member PAG (Table 1-1) representing diverse interests and a Technical Advisory Group (TAG; Table 1-2) throughout the lake protection planning process.

The PAG represented a wide variety of stakeholder groups from the public and private sectors including local elected officials, farmers, developers, water providers, landowners, large industries, property rights advocates, conservation groups, chambers of commerce, lake marinas, and planners. Although PAG members were encouraged to consider issues from a watershed-wide perspective, they were also asked to represent the issues and concerns of their constituencies in the four counties of the watershed, as well as water users outside the watershed. In addition, Tetra Tech held more than 10 focus group meetings throughout the four-county area with key constituencies to gain input and gather additional information for the PAG to consider. Early on, the PAG established guiding principles, goals, and objectives for the Strategy. The PAG served as a sounding board for watershed characterization results and possible solutions to existing water quality impairments and threats.

Table 1-1. Policy Advisory Group Participants from the 2012 Strategy

Member	Agency/Organization
Doug Timmons	Association for Beaver Lake Environment
Tony Miltich	Association for Beaver Lake Environment
Bob Morgan	Beaver Water District, Beaver Watershed Alliance
Bob Caulk	Fayetteville Natural Heritage Association, Beaver Watershed Alliance
Gene Groseclos	Cooper Communities, Beaver Watershed Alliance
Barbara Taylor	Fayetteville Natural Heritage Association, Beaver Watershed Alliance
Ed Clifford	Bentonville Chamber of Commerce-Northwest Arkansas Council
Frank Winscott	Benton County Justice of the Peace
Dan Douglas	Benton County
Scott Borman	Benton/Washington Regional Public Water Authority
Scott Bounds	Benton/Washington Regional Public Water Authority
Richard Williams	Carroll County Judge
George Phillips (observer)	Carroll County
Mike Dodge	Carroll Electric
Susan Thomas	City of Fayetteville
John Coleman	City of Fayetteville
Patsy Christie	City of Springdale, Beaver Watershed Alliance
Hunter Haynes	Haynes Limited
Larry Garrett	Huntsville Wastewater Treatment Plant
Clarence Carson	Madison County Farm Bureau
Steven Ford	Madison County USDA Conservation Officer
Don Day	Northwest Arkansas Property Rights Association
Jeff Hawkins	Northwest Arkansas Regional Planning Commission
Rob Smith	Northwest Arkansas Council
Scott Van Laningham	Northwest Arkansas Council
Craig Smith	Prairie Creek Marina
Tom McAlister	Rogers Water Utilities
Walter Turnbow	Springdale Resident
Larry Beals	Superior Industries
Tim Snell	The Nature Conservancy
Kevin Igli	Tyson Foods, Inc., Beaver Watershed Alliance
Trish Ouei	University of Arkansas Benton County Extension Service, Beaver Watershed Alliance
Katie Teague	University of Arkansas Washington County Extension Service
Juliet Richey	Washington County Planner, Beaver Watershed Alliance
Henry Griffith	West Fork Environmental Protection Association
Jane Bryant	West Fork Watershed Alliance
Mike Faupel	University of Arkansas

Table 1-2. Members of the Technical Advisory Group from the 2012 Strategy

Name	Agency
Sarah Clem	Arkansas Department of Environmental Quality
Jim Wise	Arkansas Department of Environmental Quality
Robert Hart	Arkansas Department of Health
Alan Fortenberry	Beaver Water District
Bob Morgan	Beaver Water District, Beaver Watershed Alliance
Ray Avery	Beaver Water District
Billy Ammons	CH2M-Hill, Beaver Watershed Alliance
Kent Thornton	FTN Associates, Ltd.
Nicole Hardiman	Northwest Arkansas Land Trust, Beaver Watershed Alliance
Brian Haggard	University of Arkansas
Marty Matlock	University of Arkansas
Ralph Davis	University of Arkansas
Susan Bolyard	United States Geological Survey
Reed Green	United States Geological Survey

Tetra Tech also met with focus groups representing property rights advocates, livestock and poultry producers, poultry integrators, developers, drinking water utilities, environmental and conservation groups, recreational interests, and local governments. These meetings elicited valuable input about Beaver Lake, the water quality protection goals, and solutions. The results of these discussions were shared with the PAG in their deliberations.

The TAG reviewed research, water quality data, and other scientific and technical information and provided input on the most important technical issues related to watershed and lake protection. The TAG also provided advice on water quality indicators and targets, linked to the lake protection goals, to help evaluate different options.

Tetra Tech worked with technical partners to develop a watershed modeling tool and lake response modeling tool that could help to evaluate existing conditions and predict future conditions (year 2055) under current policies. These initial modeling results were collectively referred to as the Baseline Conditions Analysis (methodology described in “Technical Memorandum: Beaver Lake SWAT Modeling Baseline Analysis" (Tetra Tech, 2009)). The modeling framework was subsequently used to predict future conditions under different water quality protection alternatives. Results were evaluated and reported considering the lake protection goals and targets. Costs for different management techniques were reviewed and evaluated to screen for the most cost-effective solutions.

Finally, solutions were also screened that could do the “double duty” of protecting Beaver Lake and addressing existing impairment in the West Fork and Lower White River subwatersheds.

These subwatersheds have Total Maximum Daily Load (TMDL) sediment allocations, which require significant reductions from existing levels. In summation, the NWA Council engaged diverse stakeholders throughout the process to ensure meaningful input and support, and conducted a technical analysis based on sound science and good engineering practices. The NWA recognized the importance of continuing to work with stakeholders to find solutions that address environmental, economic, and social concerns in the region. The PAG therefore recommended that a new group (a watershed council) be formed locally to help facilitate the implementation of the Strategy and adapt the protection measures in the future as conditions change. The result of that recommendation was the formation of the Beaver Watershed Alliance, which managed the completion of the 2012 Strategy update.

Beaver Watershed Alliance

In 2011, the Alliance was formed through a stakeholder-led process. The mission of the Alliance is “to proactively protect, enhance and sustain water quality in Beaver Lake and the integrity of its watershed.” This Alliance is described in detail in Section 4.2.1.

In spring 2012, the Alliance solicited the original PAG and TAG organizations to revise and update the Strategy. The goal of the 2012 revision was to (1) address gaps identified in the 2009 document and (2) facilitate and clarify correlation with the 9 Elements identified in the U.S. Environmental Protection Agency’s (U.S. EPA’s) *Handbook for Developing Watershed Management Plans to Restore and Protect Our Waters* (U.S. EPA, 2008). The PAG and TAG members reconvened to suggest revisions, discuss the relevancy of the document, and inform the Alliance of new and emerging issues in the watershed. Funding for the 2012 revision of the Beaver Lake Watershed Protection Strategy was provided by the U.S. EPA and the Arkansas Department of Agriculture - Natural Resources Division (ANRD).

1.3 Progress Since Adoption of the 2012 Lake Protection Strategy

The watershed has been the site of much progress since the adoption of the initial Strategy. This progress has taken the form of multiple partner collaboration for on-the-ground conservation and restoration projects, landowner engagement through Alliance programming, technical research studies completed, and a collaborative effort between nonprofit organizations, landowners, and local, state, and federal agencies, as well as many other stakeholders. Some examples of progress and success across the Beaver Lake Watershed include:

- 16.5-mile segment of the West Fork – White River delisted from the 303d list, an EPA and ANRD Nonpoint Success Story.

- Water quality monitoring stations deployed throughout the watershed
- Approximately 4 miles of streambank restored within the watershed, resulting in 25,674 ton/yr sediment reduction and 14,262 lb/yr phosphorus reduction
- Approximately 38,000 feet of riparian area restored in association with stream restoration work
- 1,305 acres of land protected permanently through land conservation (NWALT 2012-present)
- Over 20,000+ private landowners engaged through Beaver Watershed Alliance news mailers and 4,500+ engaged through digital monthly newsletter
- Septic Remediation Program (H2Ozarks and ANRD) established for the Beaver Lake watershed, assisting homeowners in repairing or replacing failing septic systems. $462,706 in funding was distributed across 37 projects, resulting in 179 acres remediated in the Beaver Lake watershed.
- Voluntary land management practices implemented through Low Impact Development (LID) and Green Infrastructure (GI) initiatives in urban areas, agricultural land management programs, forestry and pastureland programs.
- Public education and outreach programming established by local groups including University of Arkansas Division of Agricultural Extension program, "Know the Flow," Beaver Water District's Watershed Academy and youth education efforts, Beaver Watershed Alliance' Smart Growth for Source Water Protection program, landowner workshops and joint efforts including an Annual Water Conference hosted by partners including Arkansas Water Resources Center, Arkansas Forest and Drinking Water Collaborative, Beaver Watershed Alliance, Illinois River Watershed Partership, Arkansas Department of Agriculture - Natural Resources Division and Arkansas Forestry Division.
- Landowner programs for conservation delivery on private lands developed by USDA NRCS, Partners for Fish and Wildlife Service, Arkansas Game and Fish Commission, Quail Forever, Arkansas Forestry Association, Beaver Watershed Alliance, H2Ozarks, and others.
- Subwatershed-level data assessed for opportunities for unpaved road improvement opportunity areas, streambank erosion, best management practice implementation, erodible soils, land use, landowners, and pasture soil/slope analysis. Subwatershed maps include: Headwaters, Middle Fork - White River, East Fork - White River, West Fork - White River, Richland Creek, and War Eagle Creek.

- Landscape-scale initiatives for the Beaver Lake watershed, including:
    - West Fork Opportunity Assessment, Funding: Tyson - $16,000; Walton Family Foundation - $123,998, Status: Completed
    - Forest Opportunity Assessment, Funding: US Endowment - $19,800, Status: Completed
    - Lakeside Watershed Opportunity Assessment, Funding: Walton Family Foundation - $187,632, Status: Completed
    - Initiating Community Stewardship through Watershed Discovery, Funding: National Fish and Wildlife Foundation - $81,082, Status: Completed
    - Establishing Conservation Funding Mechanisms in the Beaver Lake Watershed, Funding: Healthy Watersheds Consortium Grant - $371,965, Status: Completed
    - Beaver Lake Watershed Mapping, LID Implementation, and Pond BMP Research Project, Funding: Walton Family Foundation - $998,227, Status: Completed
    - West Fork - White River Regional Conservation Partnership Program, Funding: USDA NRCS - $8 million, Status: Completed
    - White River and Richland Creek Watershed Opportunity Assessment, Funding: 319 grant - $438,251, Status: Complete
    - War Eagle Creek Opportunity Assessment, Funding: 319 grant - $279,605, Status: Completed
    - Implementing Green Infrastructure in the Beaver Lake Watershed , Funding: 319 grant - $876,812, Status: Completed
    - Lake Atalanta LID Demonstration Project in the Beaver Lake Watershed, funding: (319 grant - $407,832, Status: Completed
    - Watershed Protection Strategy, Metrics and Technical Assistance, Funding: Walton Family Foundation - $485,000, Status: Completed
    - Smart Growth for Source Water Protection in the Beaver Lake Watershed, Funding: 319 grant - $990,056, Status: In progress
    - War Eagle Creek Regional Conservation Partnership Program, Funding: USDA NRCS - $5 million, Status: In progress
    - War Eagle Creek Watershed Conservation Implementation, Funding: US Fish and Wildlife - $300,000, Status: In progress
    - War Eagle Creek Collaborative Restoration Initiative, Funding: America the Beautiful Grant - $3.9 million, Status: In progress

Specific measures of progress, success, and collaboration through Beaver Watershed Alliance activities (2013 – 2021) include:

- $8.6 million in grants and sponsorships, leveraged to over $18 million
- $1.2 million in community service contributions through volunteerism
- Comprehensive database developed for all land management activity, including metrics

- 27 Watershed Success Metrics developed and implemented
- Programming established for forestry, agriculture, urban, streamside, and youth education
- Localized educational fact sheets developed for native plants, riparian plantings, ponds, unpaved roads, gravel mining, low impact development, and projects
- Scientific studies and technical research publications completed (visit https://www.beaverwatershedalliance.org/ for more details on these studies and publications)

A visual and numerical representation of the progress made between 2016 and 2022 is demonstrated in Figure 1-1.

Figure 1-5. By the Numbers (Beaver Watershed Alliance, 2016 – 2022 Metrics)
From top left to bottom right: 2022 Arkansas Water and Watersheds Conference; Winslow Arbor Day, March 2018; AGFC Stream Team and Volunteers; Landowners attend Learn to Burn Workshop at Hobbs State Park; Josh Fortenberry, USDA Natural Resources Conservation Service talks about streambank erosion; Pasture renovation on the East Fork – White River floodplains

1.4 Development of the 2023 Revision

As part of the adaptive management process specified in the 2012 Strategy update, the Strategy recommends an annual formulation and evaluation of programs at the organizational level for the Alliance and participating stakeholder organizations, along with a five-year cycle of adaptive management as Strategy implementation occurs. In 2021, with support from the Walton Family Foundation, the Strategy underwent an update. The Alliance Technical Committee (TC) led the process to advise on the project, provide local expertise, and weigh in on discussion points and prioritization criteria decisions. RTI International was selected through a competitive bid process to complete a revised watershed-based assessment of protection strategies and update the Strategy document. RTI is an independent, nonprofit research institute dedicated to improving the human condition. RTI's Center for Water Resources includes scientists and engineers with expertise in developing tailored, innovative, end-to-end water management solutions to strategically manage dynamic environmental challenges.

Prior to selection by the Alliance, RTI was engaged by the District to develop a watershed model for the Beaver Lake Watershed to identify priority areas for source water protection activities. This complementary assessment provided updated, foundational information on the current and future potential land-derived sources of runoff and water quality loadings (sediment, nitrogen, and phosphorus) at the local catchment scale, as defined by the enhanced National Hydrography Dataset (NHDPlus) (Section 2.2).

For the 2023 Strategy revision, RTI used the information on land-derived water quantity and quality loads and the metric-based prioritization framework developed for the District (RTI International, 2022) to work with the TC to prioritize the catchments across the watershed for addressing land-derived sources of sediment, nitrogen, and phosphorus through land restoration and conservation and other conservation practices. This watershed-based assessment for prioritization is supplemented with more-site specific field-based information on unpaved roads and in-channel sources of water quality loads due to streambank erosion. These two sources of sediment were accounted for through work conducted by Arkansas Department of Environmental Quality (ADEQ) (Arkansas Department of Environmental Quality, 2004), the Watershed Conservation Resource Center (WCRC), and partners beginning in 1998 through present. Priorities for channel-source sediment for the West Fork White River were developed based on monitoring, modeling, and assessment of these sources. WCRC partnered with the Alliance to develop priorities for unpaved road sediment reduction for Beaver Lake subwatersheds using geospatial analysis. The WCRC has been highly successful in obtaining funding and completing projects to address streambank erosion and to restore stream channels to more natural states since the last Strategy. This update reflects those efforts and the sources of water quality degradation monitored and addresses the completed and upcoming efforts as well as the prioritization of future work.

The Alliance TC led the process, with stakeholder engagement at the local, state, and federal level to review the technical components and documentation of this Strategy update. In March 2023, the Strategy was adopted by the Alliance Board of Directors.

Table 1-3 provides dates of Strategy updates and revisions.

Table 1-3. Summary of Beaver Lake Watershed Protection Strategy Updates and Revisions

Year	Activity	Firm	Project Lead
2009	Beaver Lake Watershed Protection Strategy (Strategy) initiated	Tetra Tech	NWA Council
2011	Strategy submitted to EPA; Beaver Watershed Alliance formed		Beaver Watershed Alliance
2012	Revisions completed; Strategy accepted as first 9-Element Plan in Arkansas		Beaver Watershed Alliance
2023	Strategy updated	RTI International	Beaver Watershed Alliance
2024	Strategy final revisions	Water Quality Specialists	Beaver Watershed Alliance

1.5 EPA's 9 Elements for Watershed Management Plan Development

Table 1-4 summarizes the components of EPA's 9 Elements for Watershed Management Plan Development, and how the Beaver Lake Watershed Protection Strategy addresses those items. A full version of this table is included in Appendix C.

Table 1-4. EPA 9 Elements – Beaver Lake Watershed Protection Strategy Component Correlation Quick Reference Guide

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA'		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
a) Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any	3-12 46-83	**Section 1.1** Why are These Protection Measures Needed **Section 2.2:** Existing and Future Loads to the Lake	**Section 1.1.** provide historical water quality context. **Section 2.2** discusses the existing and future loads to the Lake,	ADEQ 303D Lists Conservation Assessment of Beaver Lake Watershed (RTI

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA'		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.	93-96 137-146	**Section 2.4** Priority Watershed Issues **ENVIRONMENTAL GOALS**	including a discussion of the various load sources considered and a discussion of the modeling. **Section 2.4** provides context to the list of impaired waters. This section defines environmental goals and monitoring strategy.	International, 2022) Grantz and Haggard 2023
b) An estimate of the load reductions expected from management measures.	147	**Section 4.3:** Management Measures, Costs, and Load Reduction Estimates	**Table 4-7** includes estimated load reduction efficiencies achieved through management measures used within the watershed.	Conservation Assessment of Beaver Lake Watershed (RTI International, 2022)
c) A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element b, and a description of the critical areas in which those measures will be needed to implement this plan.	137-146 110-132	**ENVIORNMENTAL GOALS** **Section 4.2.2:** Component #2 – Conservation Practices	This section defines environmental goals and monitoring strategy. **Section 4.2.2** includes descriptions of nonpoint source management measures, termed conservation practices that improve load reductions.	
d) Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	109-132 187-194 153-181	**Section 4.2:** Four Components of Updated Protection Strategy **Appendix A:** Conservation practices Cost and Cost Effectiveness **Section 5:** Proposed Beaver Lake	**Section 4.2:** Four Components of Updated Protection Strategy and Appendix A for cost information; see **Section 5** for Beaver Lake Watershed Protection Implementation Summary.	

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA'		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
		Watershed Protection Strategy Summary		
e) An information and education component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	110-132 133-134	**Section 4.2.2:** Component #2 – Conservation Practices **Section 4.2.3:** #4 Education and Outreach Program	See **Section 4.2.2** #2 Conservation Practices, and **Section 4.2.3** #3 Education and Outreach Program for training, education, and outreach components.	
f) Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	168-180 168	**Section 5.3:** Implementation Timeline **Table 5-4.** Beaver Lake Watershed Protection Strategy Implementation Timeline	See **Section 5.3** and associated table for Implementation Timeline.	
g) A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.				
h) A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.	83-92 93-96 137-146	**Section 2.3:** Water Quality Standards **Section 2.4** Priority Watershed Issues **ENVIRONMENTAL GOALS**	**Section 2.3:** Water quality criteria to measure progress. **Section 2.4:** the list of impaired waters. This section defines goals and monitoring strategy.	
i) A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the	135-145	**Section 4.2.4:** Component #4 Monitoring and Adaptive Management	**Section 4.2.4:** Component #4 Monitoring and Adaptive Management	

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA'		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
criteria established under element h.				

2 Description of the Watershed

2.1 Watershed Size, Location, and Natural Features

Beaver Lake is in the Ozark Highlands of northwest Arkansas's Benton, Carroll, Madison, and Washington Counties in the headwaters of the White River. The U.S. Army Corps of Engineers constructed the multipurpose reservoir in the mid-1960s for flood control, generation of hydroelectric power, and public water supply. The Beaver Lake watershed is 1,192 square miles, and includes portions of Benton, Carroll, Washington, and Madison counties and 17 incorporated municipalities or villages (Figure 2-1). A small fraction of the watershed lies in Crawford and Franklin counties. As defined by the PAG, the watershed was defined as only the tributaries/reservoir upstream from Beaver Lake Dam.

Major streams in the watershed draining to the lake include the West Fork of the White River, the Middle Fork of the White River, the East Fork of the White River, Richland Creek, and War Eagle Creek. These were divided into eight subwatersheds for the purposes of evaluating existing and future watershed conditions and developing the Protection Strategy (Figure 2-2).

The lake covers approximately 44 square miles and is about 50 miles long. The lake contains, on average, 539 billion gallons of water. The depth of the lake at the dam is about 200 feet, but its average depth is 60 feet. The mean retention time for water in the reservoir is 1.5 years (i.e., the time for water to move from the upper lake to the lower lake and flow through the dam). Operated by the Corps of Engineers as part of a chain, Beaver Lake is the most upstream and youngest in the series of major reservoirs on the White River mainstem. Downstream from Beaver Lake are Table Rock Lake, Lake Taneycomo, and Bull Shoals Lake.

One notable feature of the Beaver Lake watershed is its relatively steep topography. Around 40% of the Beaver Lake and East Fork subwatersheds, and nearly 30% of the Middle Fork subwatershed, have a 12% slope or higher. Additionally, soil in the watershed are highly erosive and over 45% of the watershed is ranked moderate to severe in soil erosion hazard potential. Similarly, the highly porous karst topography in the watershed presents special challenges regarding water quality protection and losses from the stream. These natural watershed features pose water quality challenges especially when coupled with the region's land uses and new development. While slope and erosivity of the land surface are readily characterized within available geospatial datasets leading to an understanding of their impacts on water quantity and quality, the specific locations, rates, and transport capacity of surface-groundwater interactions through karst areas is less documented, limiting the ability to assess these impacts.

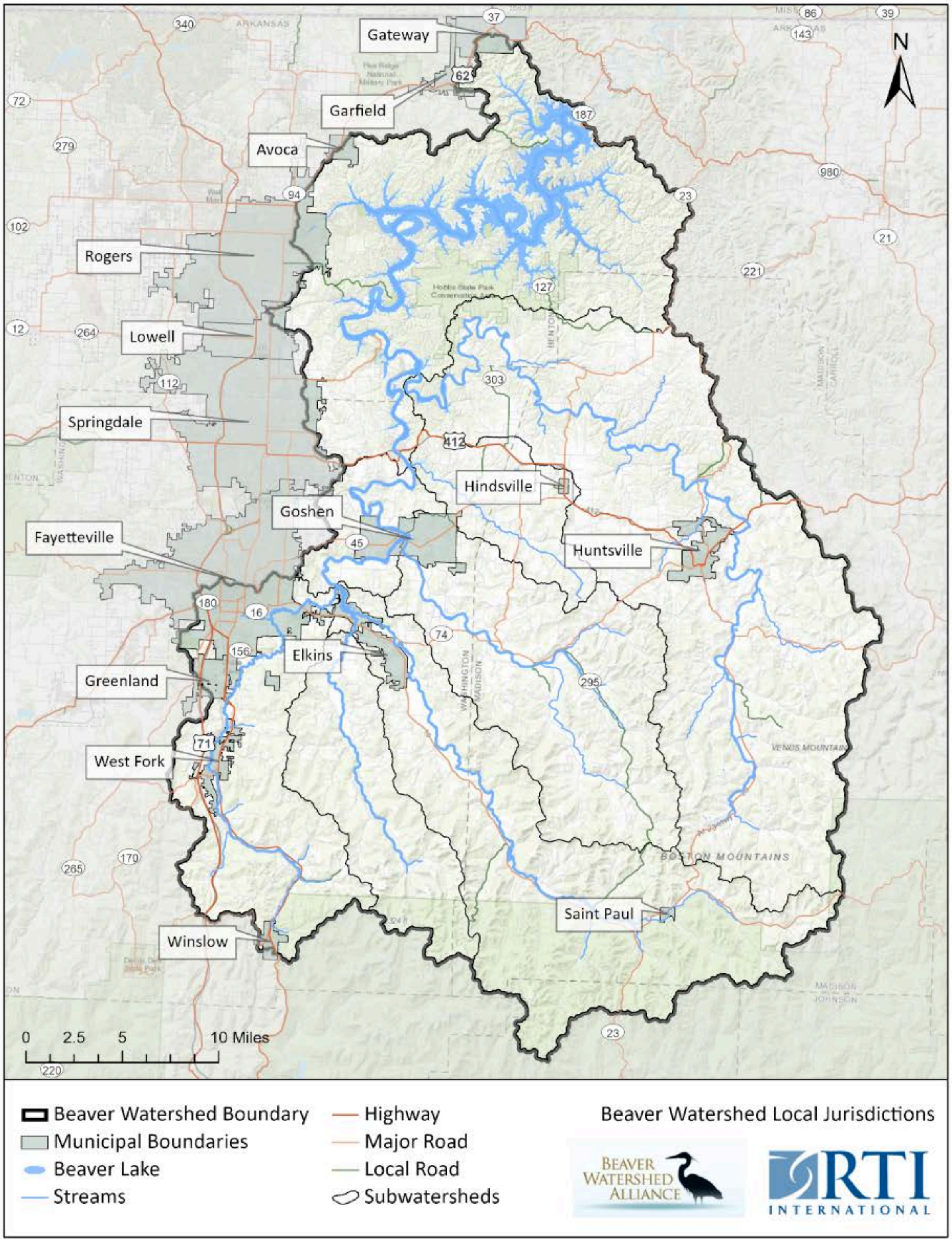


Figure 2-1. Beaver Lake Watershed and 2022 Local Jurisdiction Boundaries

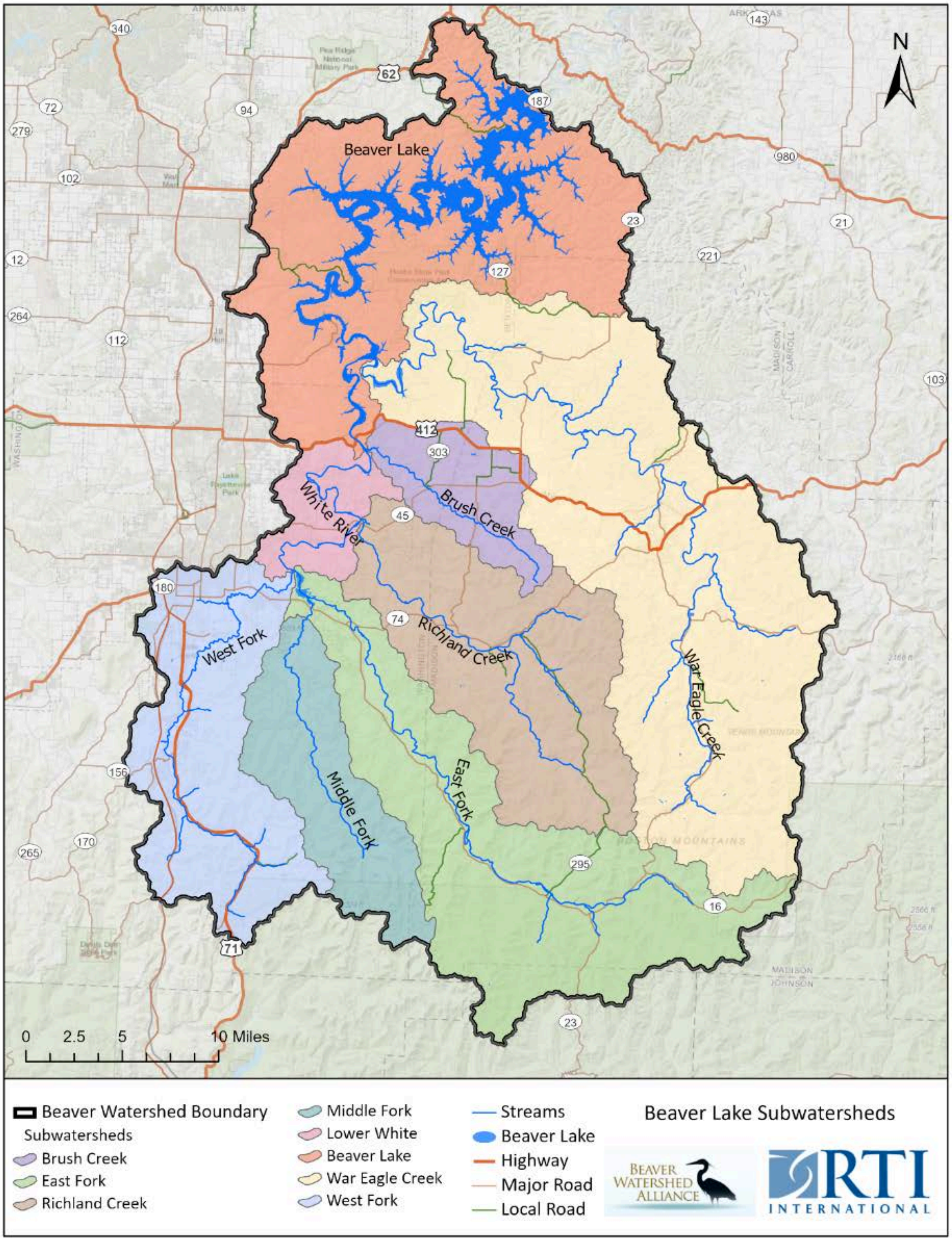


Figure 2-2. Beaver Lake Subwatersheds Defined for Watershed Strategy

2.1.1 Population and Metro Areas

In recent years, the Northwest Arkansas region has been the fastest growing area of the state—led by the Fayetteville-Springdale-Rogers Metropolitan Area located along the western boundary of the watershed. Census data from 2020 show population trends consistent with those described in the *2012 Watershed Protection Strategy*: more people are moving into urban centers like Rogers, Fayetteville, and Springdale while smaller towns are losing population. According to the 2020 census, Benton County's total population rose 28.5% from 2010. Yet only 5 of the county's 19 cities and towns matched that rate. Rogers, one of the county's biggest cities, grew just shy of 25%. Three of the county's smaller towns lost population. Washington County's total population went up 21% from 203,065 in 2010 to 245,871 in 2020. Half of that increase came from growth in Fayetteville. Fayetteville is now Arkansas' second-largest city, with 93,949 residents and followed by Springdale with 84,161 residents. These population trends, shown in Figure 2-3, are reflected in the land use of the watershed with the development of pastureland and the urbanization of dispersed exurban areas. These changes will likely impact the watershed and its water quality in the coming decades (RTI International, 2022).

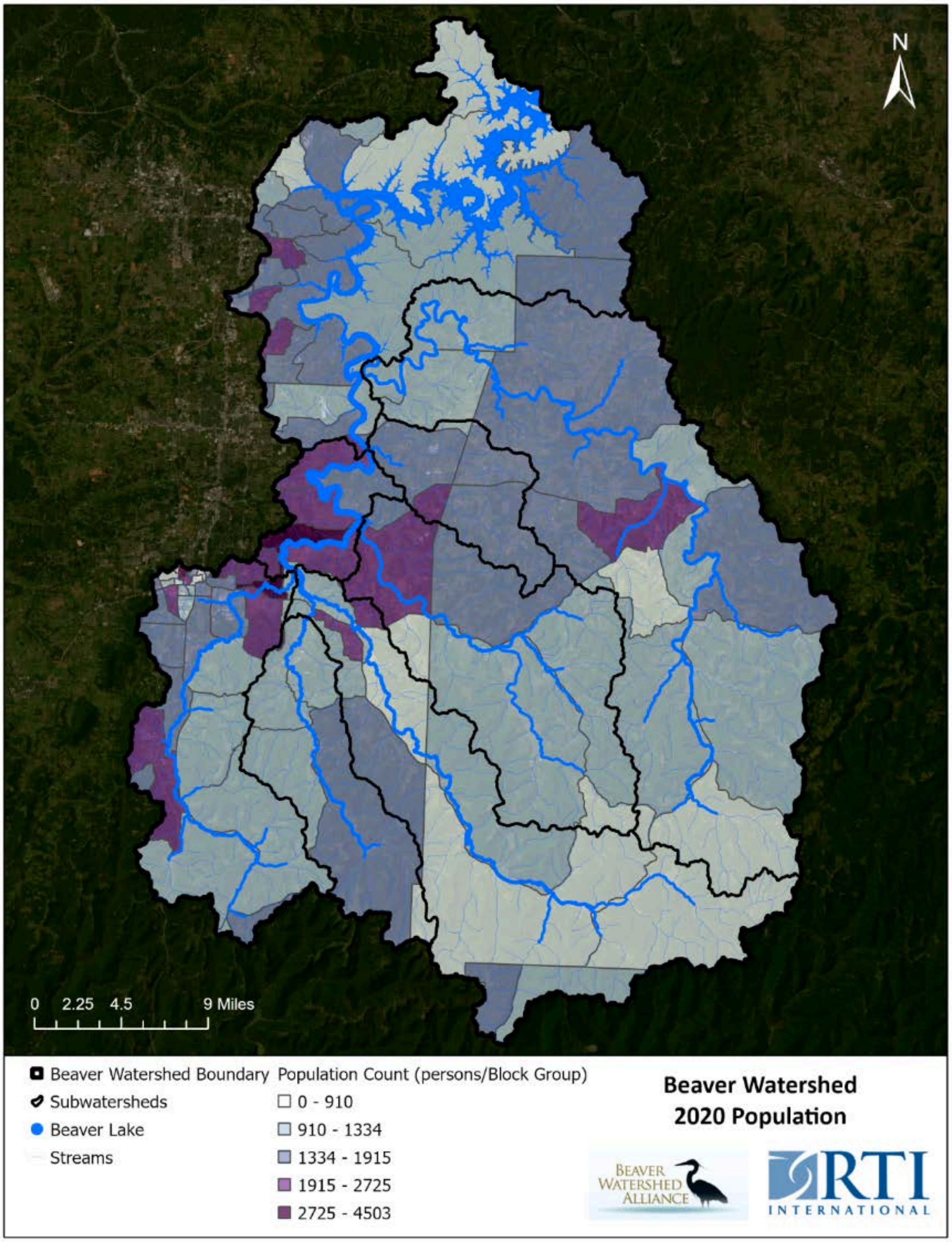


Figure 2-3. 2020 Population Estimates for Each Block Group in Beaver Lake Watershed

2.1.2 Land Use and Land Cover

The National Land Cover Database (NLCD), developed by the U.S. Geological Survey (USGS), geospatially represents the land cover or the resource or material that is covering the land surface for the United States. This dataset has a resolution of 30 meters and is available for certain years between 2001 and 2019.

The Integrated Climate and Land Use Scenarios (ICLUS) Land Use dataset is produced by the U.S. EPA and represents the way humans use the lands with a resolution of 90 meters across the United States. ICLUS data are used to assess future land use conditions given human migration and density patterns responding to climate changes. Both current (2020) and projected future land use (by decade through 2100), based on the Intergovernmental Panel on Climate Change (IPCC)'s fifth assessment scenarios and pathways are available for download. Scenarios represent different levels of long-term emissions of greenhouse gases to drive the global climate models (GCMs) and are denoted by their Representative Concentration Pathway (RCP). Four RCPs were modeled representing a range of emissions trajectories. The Shared Socioeconomic Pathways (SSPs) represent different projected futures characterized by population growth, economic growth, urbanization, trade, energy, and agricultural systems. Four SSPs were modeled encompassing a range of human development and environmental action. SSP5 and RCP8.5 – the more "pessimistic" projections (i.e., large growth in fossil fuels), were selected for the 2020 (current) and 2050 (selected future period) land use scenario inputs. The SSP governs the population dynamics of the ICLUS model whereas the RCP represents the environmental drivers for human population change. With the SSP and RCP selected, the final decision on ICLUS input to make was the selection from the two GCMs of the Coupled Model Inter-Comparison Project 5 (CMIP5) used to develop two versions of the projected future. After examining the future climate patterns, the Goddard Institute for Space Science E2-R (GISS-E2-R) GCM was selected as it presented more frequent wet months and projected an overall higher volume of precipitation in the future than the alternative GCM available from ICLUS.

With the selection of both datasets, the combination of the land cover and use is used to explain the conditions within the watershed. The classification categories for the 2019 NLCD and the 2020 ICLUS land use dataset are shown in Figure 2-4.

Code	NLCD Description
11	Open Water
12	Perennial Ice/Snow
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
52	Shrub/Scrub
71	Grasslands/Herbaceous
81	Pasture/Hay
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

Code	Group	ICLUS Description
0	*Water*	Natural Water
1		Reservoirs, Canals
2		Wetlands
3	*Protected*	Recreation, conservation
4	*Working/ Production*	Timber
5		Grazing
6		Pasture
7		Cropland
8		Mining, barren land
9	*Developed*	Parks, golf courses
10		Exurban, low density
11		Exurban, high density
12		Suburban
13		Urban, low density
14		Urban, high density
15		Commercial
16		Industrial
17		Institutional
18		Transportation

Figure 2-4. Comparison of NLCD Classifications vs. ICLUS Classifications

The combination of the two layers was necessary to provide an assessment of current and future conditions within the watershed given that (1) land cover is more representative of the information needed about the land surface to estimate runoff, sediment, and nutrient dynamics but (2) land use allows for projections into the future. From the land cover and corresponding soil conditions within each assessed area within the watershed, a parameter known as the Curve Number can be assigned, which reflects the runoff response for that area. The Curve Number method provides a means to estimate runoff, which in turn can be used to help simulate the hydrologic cycle for an area. Simulating the hydrologic cycle subsequently allows simulation of the corresponding sediment and nutrient dynamics within the surface soils and subsurface. By understanding the relationship between the current land cover and use (Figure 2-6) and given the projected land use into the future, RTI developed a set of rules to generate projected Curve Numbers across the watershed for 2050 conditions. These methods are described in the District’s Conservation Assessment Report (RTI International, 2022).

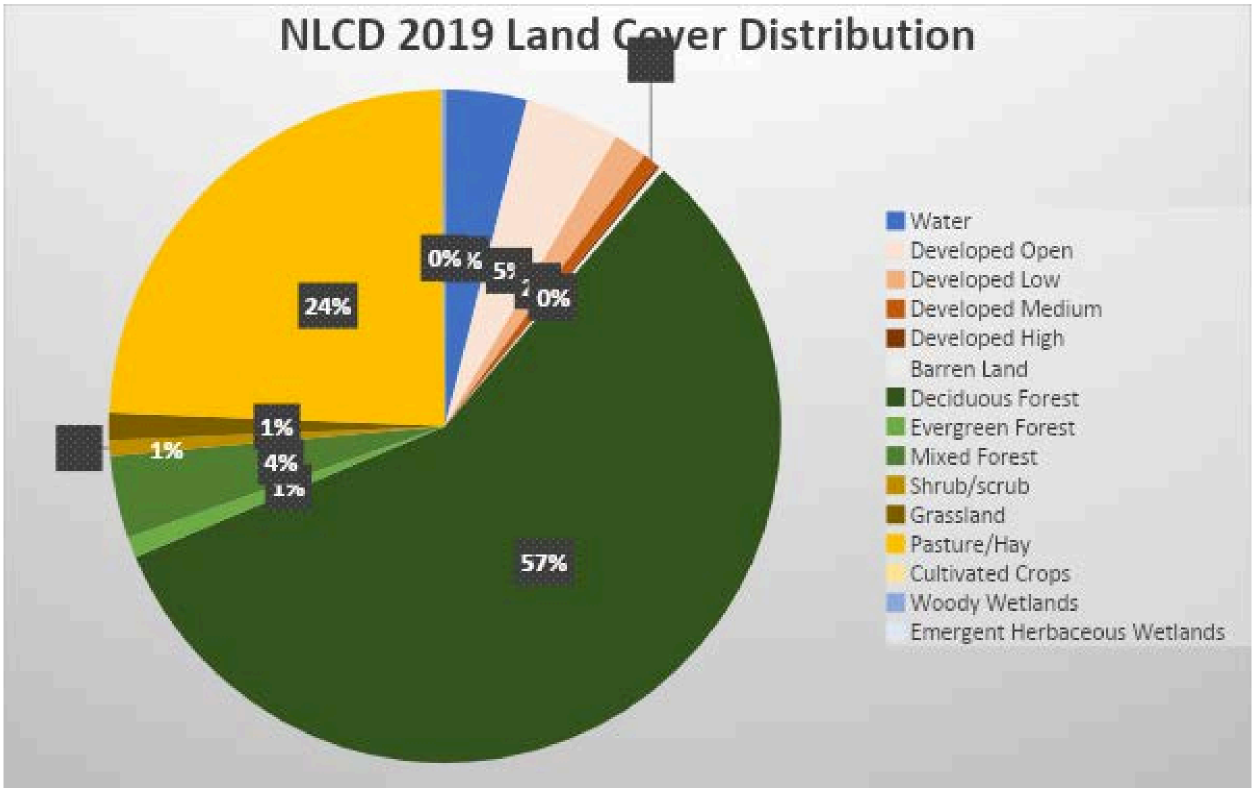


Figure 2-5. Beaver Lake Watershed Land Cover Distribution According to NLCD 2019

2.1.2.1 Current Land Use and Land Cover

The region has a unique distribution of land types, as well as notable trends projected for the future. According to the NLCD 2019 dataset, the region's primary land cover is Forest (62%) and Pasture/Hay (24%), as represented graphically in Figure 2-5 and spatially in Figure 2-6.

Similarly, the region's primary land *uses* consist of Timber (42%); Exurban, low developed (21%); and Pasture (15%), according to the 2020 ICLUS dataset. The "Exurban, low developed" land use describes regions of "residential land use beyond the urban/suburban fringe that is composed of parcels or lots that are generally too small to be considered productive agricultural land use" (U.S. EPA, 2009). In addition to Exurban, high developed (7%), a low-density residential development located outside suburbs, cities, and towns yet still connected to an urban center, the Suburban (1%) land use makes up the largest area of all more highly developed land uses (RTI International, 2022).

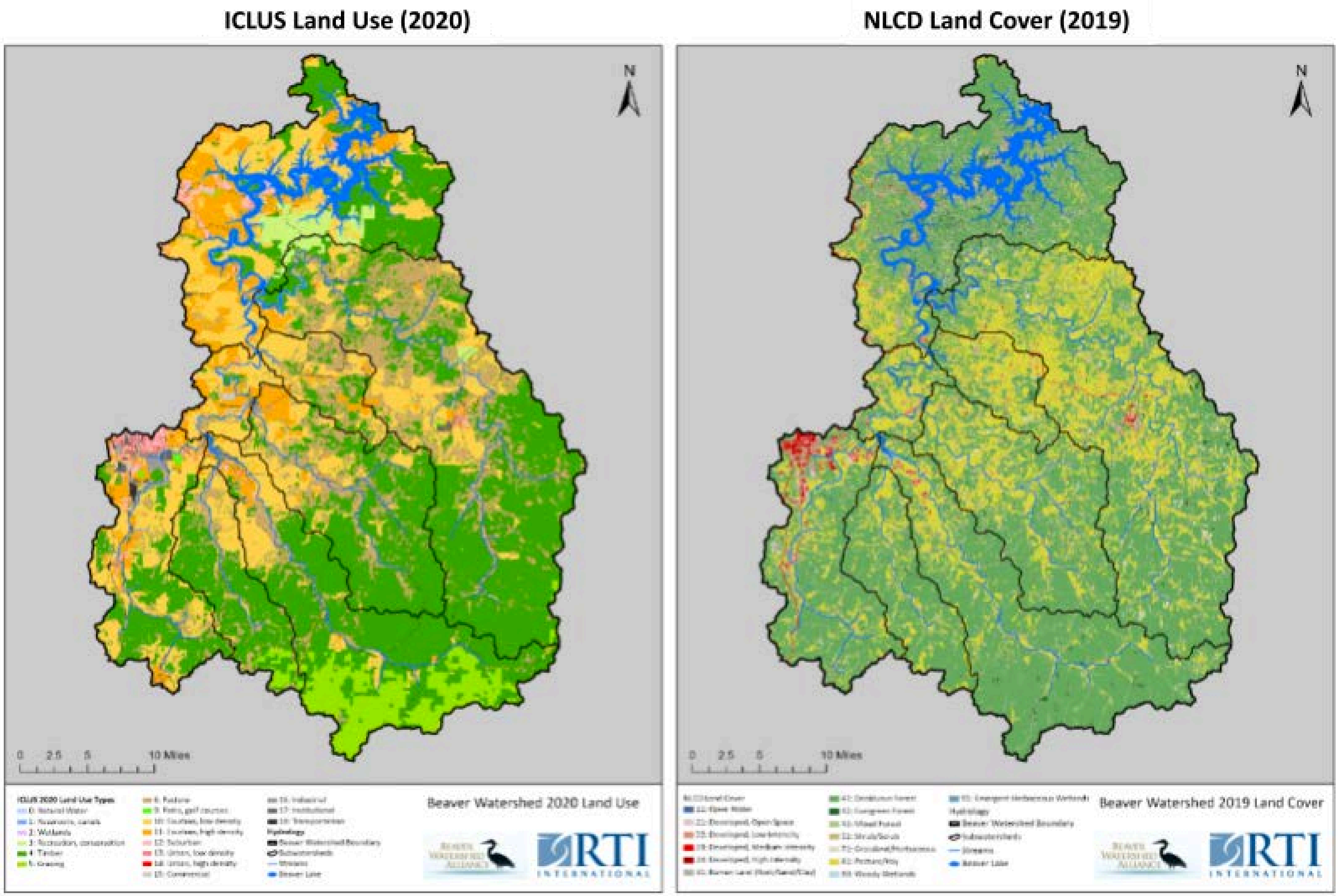


Figure 2-6. Comparison of Current ICLUS Land Use Data and NLCD Land Cover Data for Beaver Lake Watershed

2.1.2.2 Future Land Use

Figure 2-7 and Figure 2-8 show how land use is projected to change between 2020 and 2050. While forested areas (best described by ICLUS as "Timber" as ICLUS defines land use not land cover[1]) only experienced a 1% decrease in area, 10% of pastureland has been converted to other land uses, as seen in Table 2-1. Some of these land uses include suburban and exurban high development (low-density residential development located outside suburbs, cities, and towns yet still connected to an urban center), increasing 16% and 30% respectively. Urban low (69%) and high (82%) development had the largest increases in land use area, with commercial (53%) and industrial (15%) also expanding in the area. It is important to note that these percent changes are respective to the total 2020 land use classification area. Compared to the total watershed area, the percent change is much smaller, only showing a significant change in pastureland (1% decrease) and exurban high development (1% increase). This is due to the very large area of pasture and forested area in the watershed, comprising 57% of the total watershed area. While the urbanized areas are growing significantly, these areas still make up a small proportion of the watershed. Furthermore, these projections are based on current plans and development models and contain a degree of uncertainty. However, the trends evident in these projected changes – developing pastureland and urbanizing dispersed exurban areas – will likely impact the watershed and its water quality in the coming decades.

[1] Forested areas in the watershed expand beyond areas defined by ICLUS as having a land use of "Timber." Other land uses that can have a NLCD Land Cover as Forest include "Exurban, low," "Exurban, high," "Recreation, conservation," and "Parks, golf courses."

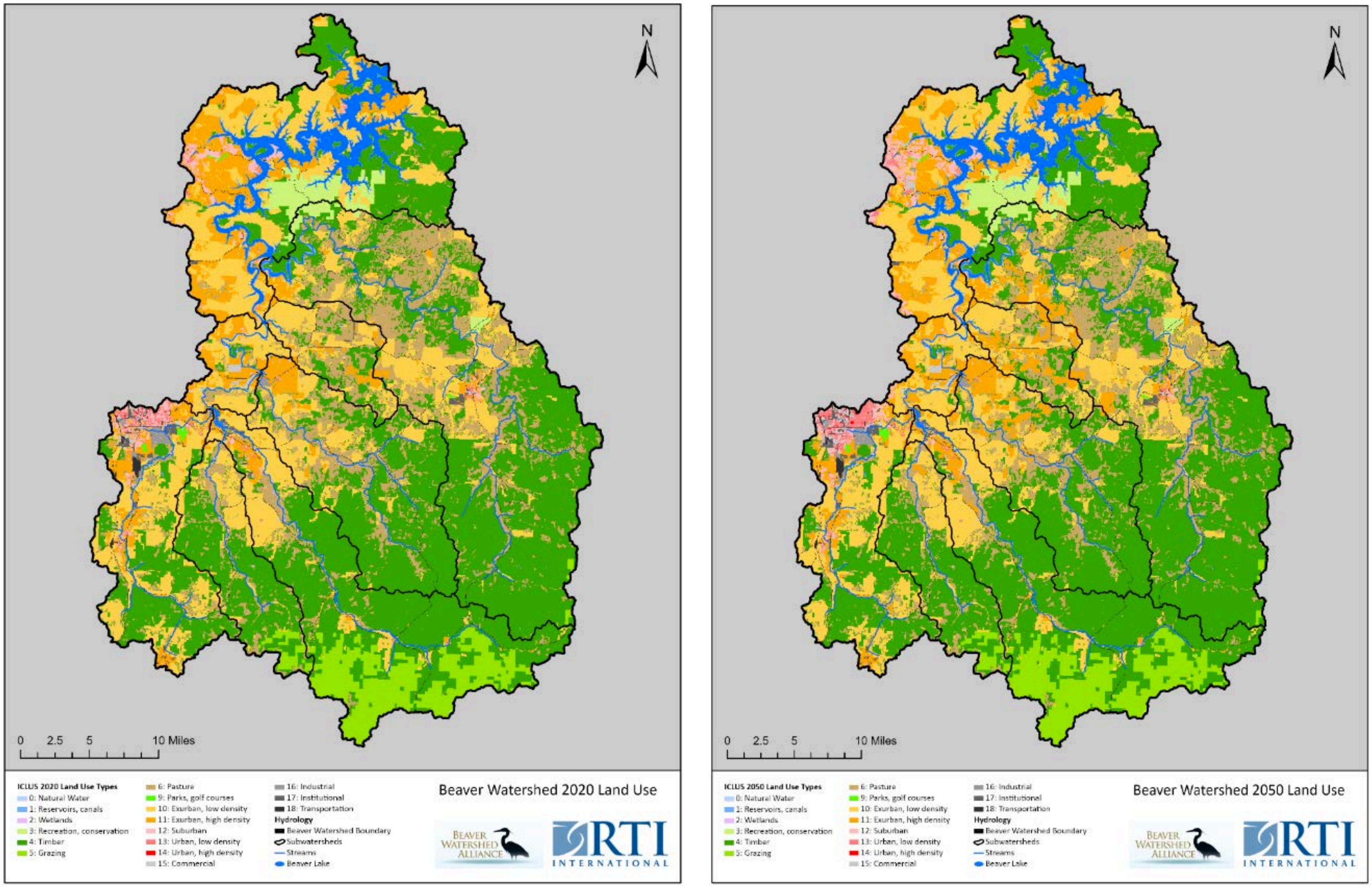
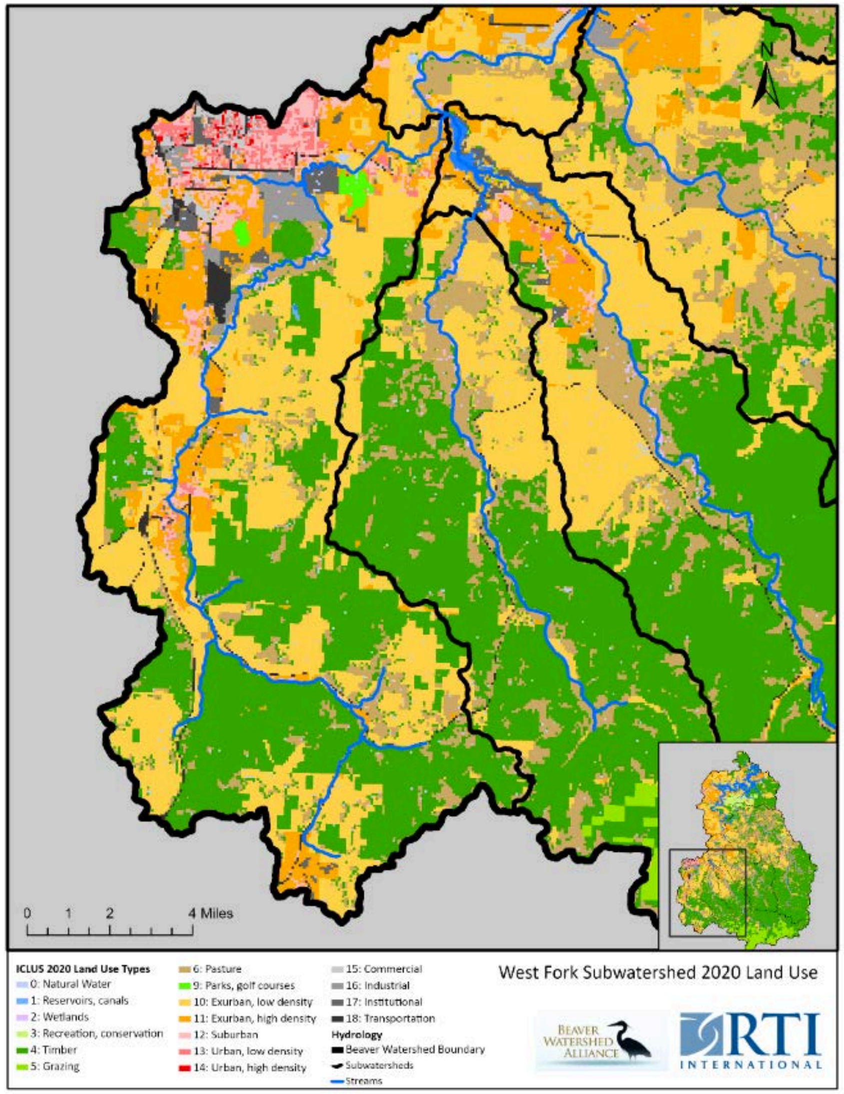


Figure 2-7. Comparison of ICLUS 2020 and Projected 2050 Land Uses in the Beaver Lake Watershed


N
0 1 2 4 Miles
ICLUS 2020 Land Use Types
0: Natural Water
1: Reservoirs, canals
2: Wetlands
3: Recreation, conservation
4: Timber
5: Grazing
6: Pasture
9: Parks, golf courses
10: Exurban, low density
11: Exurban, high density
12: Suburban
13: Urban, low density
14: Urban, high density
15: Commercial
16: Industrial
17: Institutional
18: Transportation
Hydrology
Beaver Watershed Boundary
Subwatersheds
Streams
West Fork Subwatershed 2020 Land Use
Beaver Watershed Alliance
RTI International

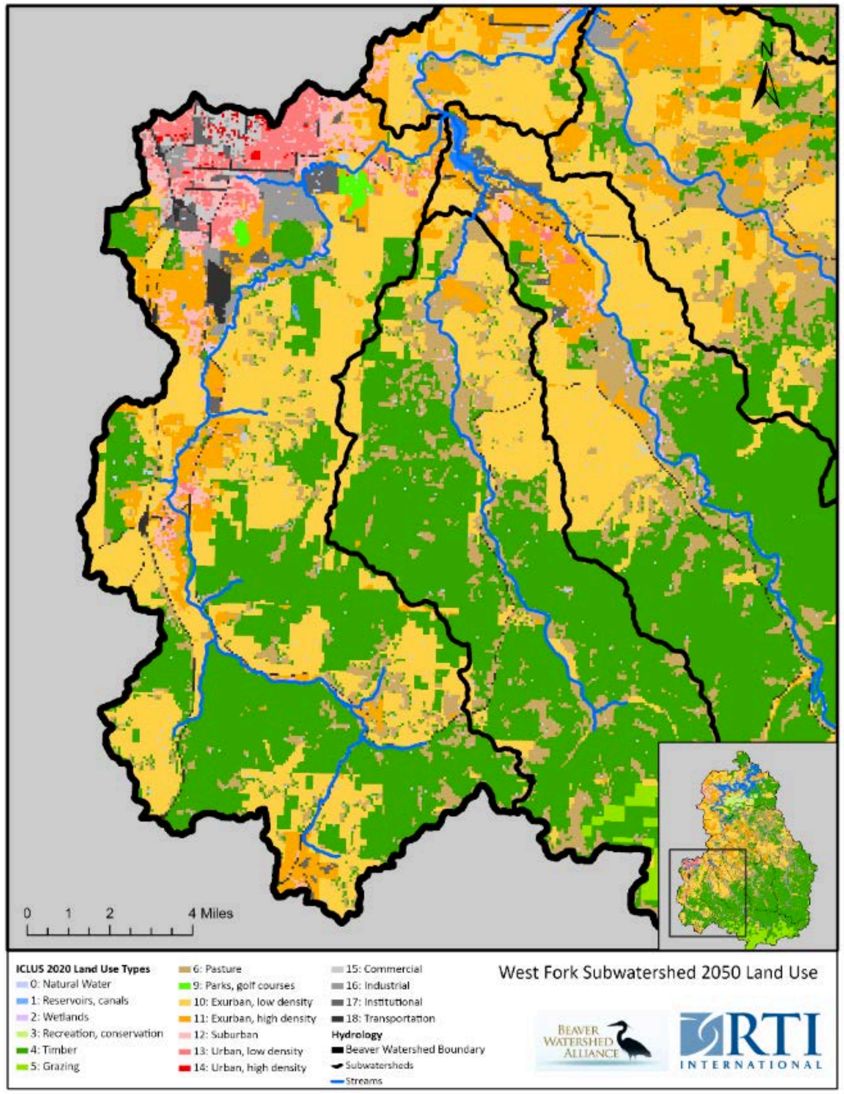


Figure 2-8. Comparison of ICLUS 2020 and Projected 2050 Land Uses in the West Fork and Richland Creek Subwatersheds

Table 2-1. Changes in ICLUS 2020 and 2050 Area in Beaver Lake Watershed

ICLUS Type	Type Description	2020 ICLUS Area (acres)	2020 Percent of Total Area	2050 ICLUS Area (acres)	2050 Change in Percent of Total Area (%)	2020 to 2050 Change in Land Use Area (%)
0	Natural Water	4013	1%	4013	+0%	+0%
1	Reservoirs, canals	29945	4%	29945	+0%	+0%
2	Wetlands	2320	0%	2314	+0%	+0%
3	Recreation, conservation	12754	2%	12754	+0%	+0%
4	**Timber**	321853	42%	319307	+0%	**-1%**
5	Grazing	36006	5%	35856	+0%	+0%
6	**Pasture**	117573	15%	106302	**-1%**	**-10%**
9	Parks, golf courses	616	0%	616	+0%	+0%
10	**Exurban, low**	158683	21%	157746	+0%	**-1%**
11	**Exurban, high**	56756	7%	65891	**+1%**	**+16%**
12	**Suburban**	8901	1%	11601	+0%	**+30%**
13	**Urban, low**	2618	0%	4427	+0%	**+69%**
14	**Urban, high**	166	0%	302	+0%	**+82%**
15	**Commercial**	1599	0%	2442	+0%	**+53%**
16	**Industrial**	1919	0%	2206	+0%	**+15%**
17	Institutional	2924	0%	2924	+0%	+0%
18	Transportation	5827	1%	5827	+0%	+0%
	Total Area	764474		764474		

2.1.2.3 Impervious Area

Impervious area is another important dataset to understand because highly impervious areas channel rainfall quickly into streams, causing bank erosion and sediment inputs to the lake. Figure 2-9 compares the percentage of impervious areas in 2020 and 2050. Based on studies conducted by the Center for Watershed Protection and other groups, when watersheds have greater than 10% impervious area most indicators of stream water quality decline (Center for Watershed Protection, 2003). In some watersheds, degradation begins with as little as 5 or 6% imperviousness. Figure 2-9 demonstrates that there is expected to be a significant growth in this level of imperviousness in the western portion of the watershed and the Huntsville area, coinciding with the growth seen in this area noted in the 2020 census. These data are sourced from EPA's ICLUS dataset as previously described in this section.

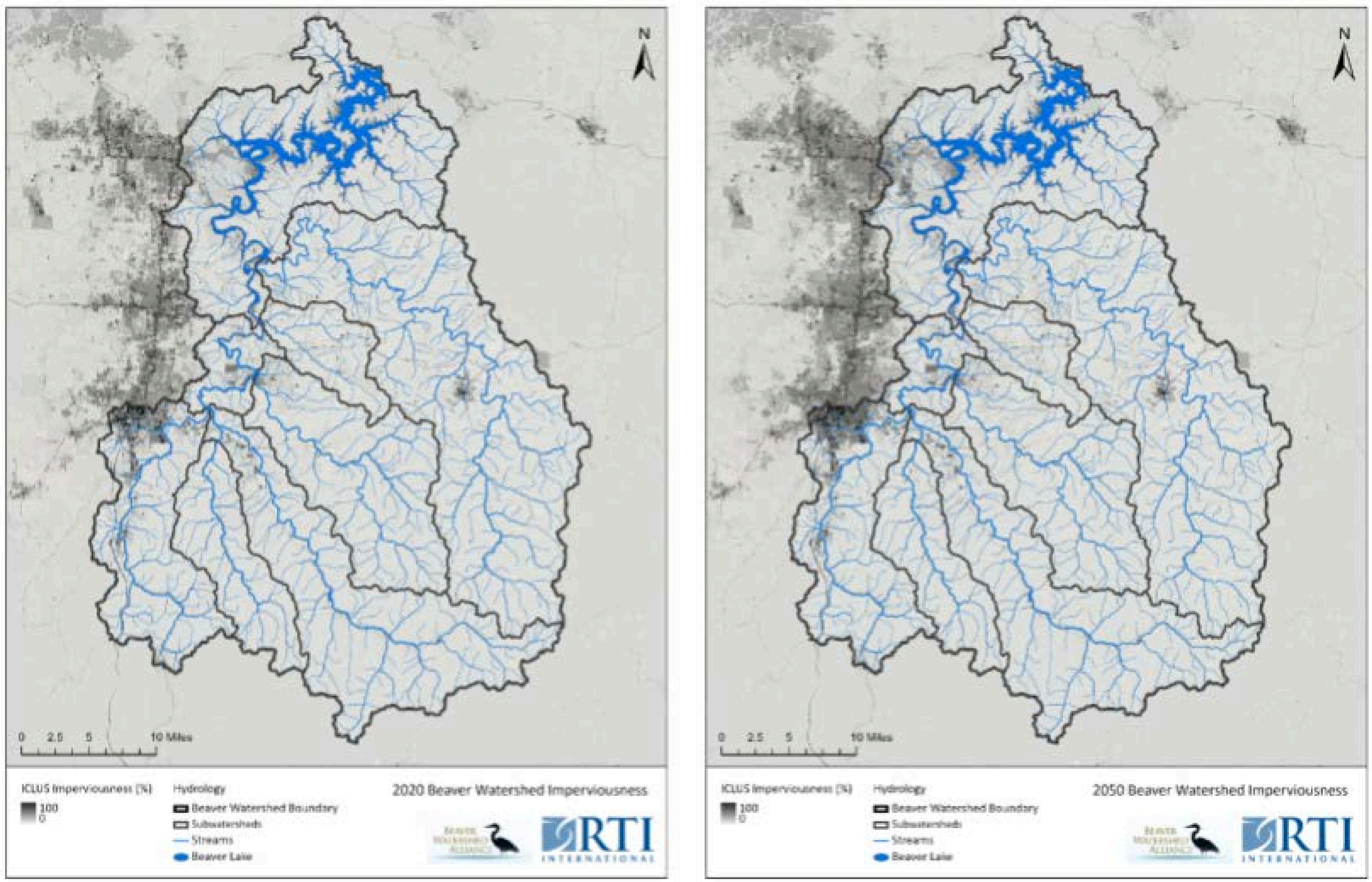


Figure 2-9. Comparison of 2020 and Projected 2050 Imperviousness using EPA ICLUS Data for Beaver Lake Watershed

2.1.3 Climate

Climate data for the region were collected from the PRISM Climate Group. PRISM data are a set of climate observations from a wide range of monitoring networks, with applied sophisticated quality control measures, and spatial climate datasets that reveal short- and long-term climate patterns. The normal shown in this section for the region are baseline datasets describing average monthly and annual conditions over the most recent three full decades. The most recent PRISM normal are for the period 1991 – 2020. Long-term average datasets for precipitation, maximum temperature, and minimum temperatures were modeled with PRISM using a digital elevation model (DEM) as the predictor grid. The following three figures (Figure 2-10, Figure 2-11, and Figure 2-12) display the 30-year normal for precipitation and temperature annual averages. The four counties of the Beaver Lake Watershed are outlined in red.

As shown in Figure 2-10 through Figure 2-12, the 30-year normal annual precipitation is in the 40 – 60-inch range, the 30-year normal maximum temperature is in the 65 – 71°F range, and the 30-year normal minimum temperature is in the 46 – 49°F range.

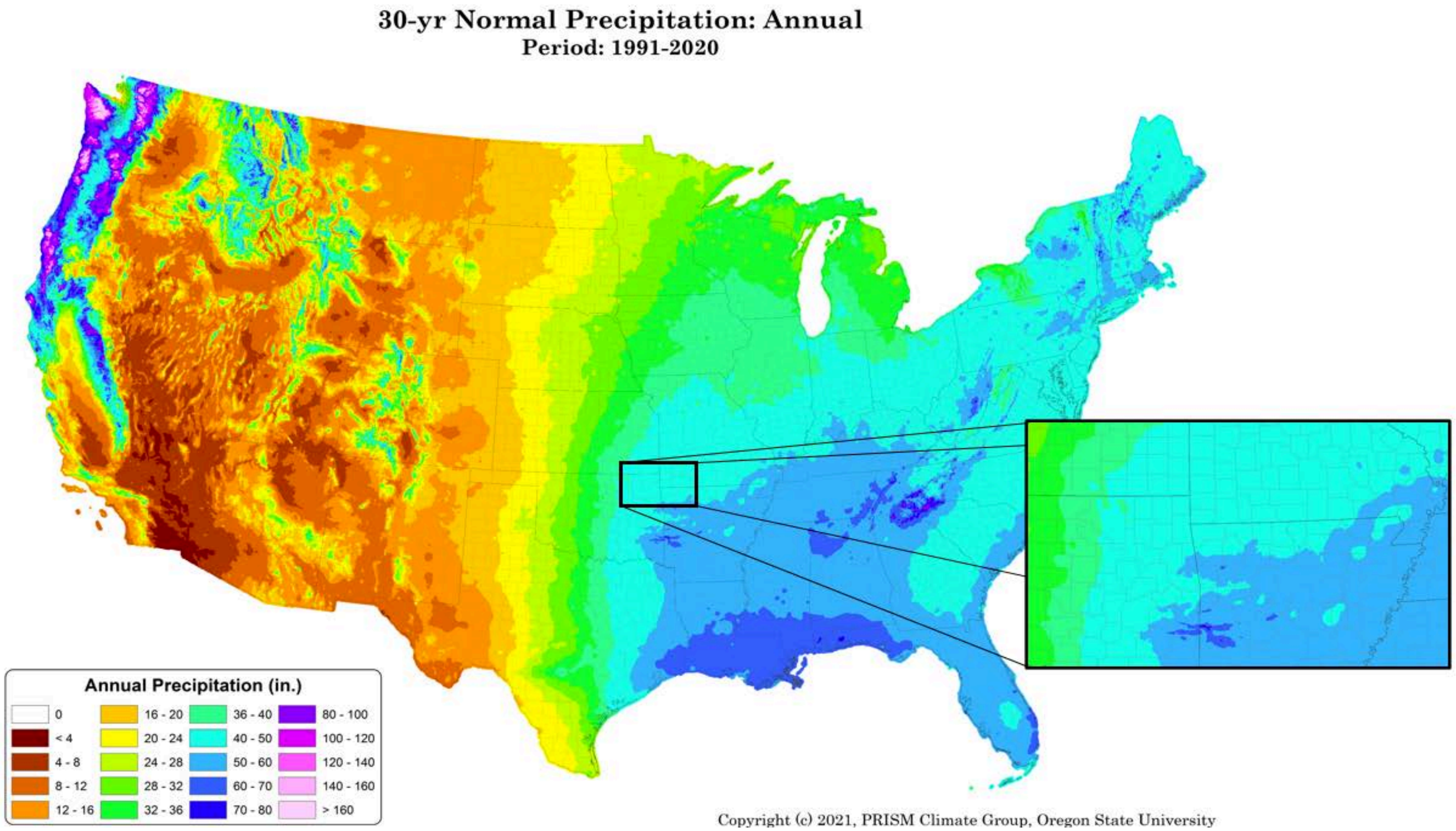


Figure 2-10. PRISM 30-year Normal Precipitation Data (1991-2020)

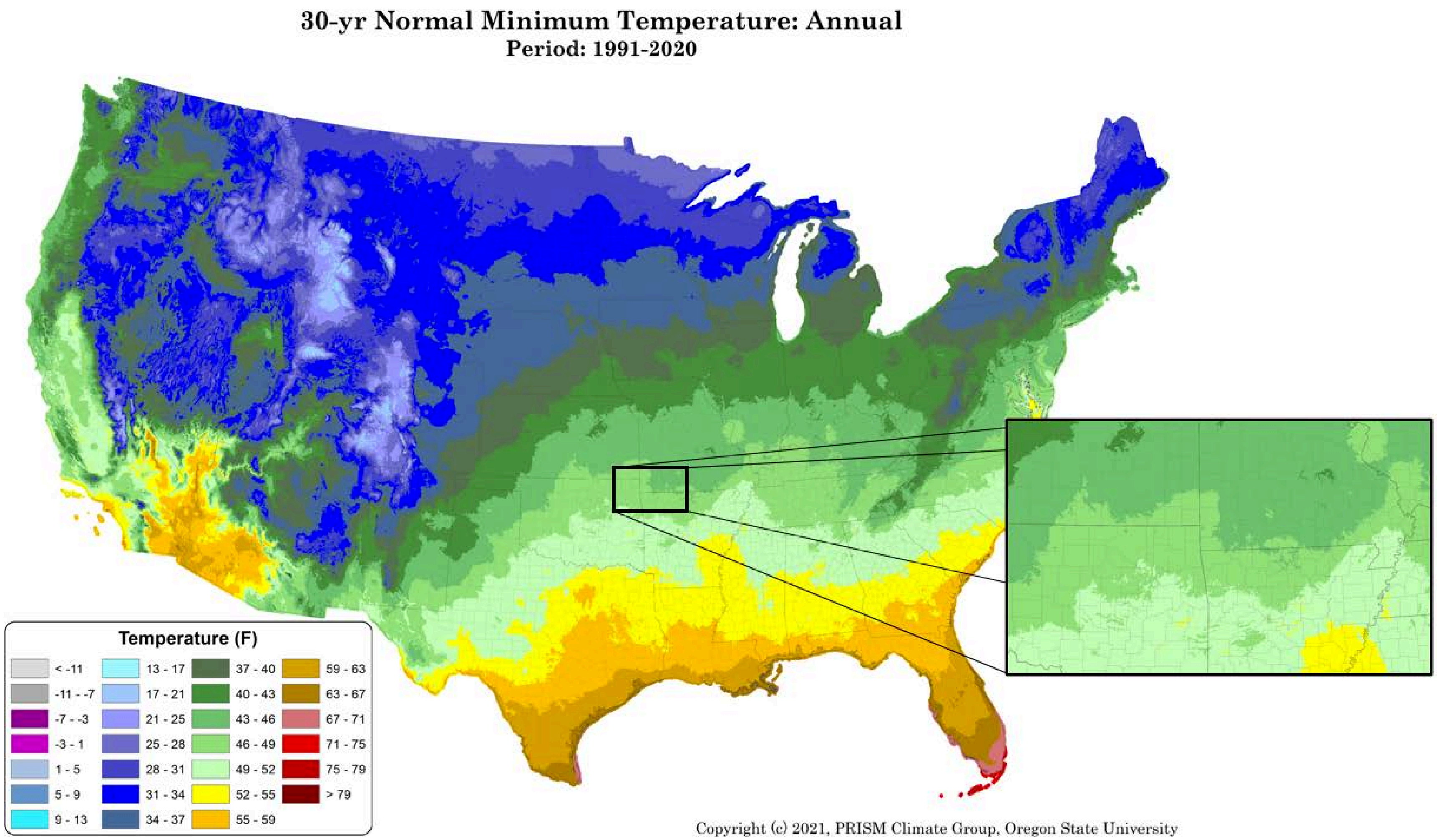


Figure 2-11. PRISM 30-year Normal Minimum Temperature Data (1991-2020)

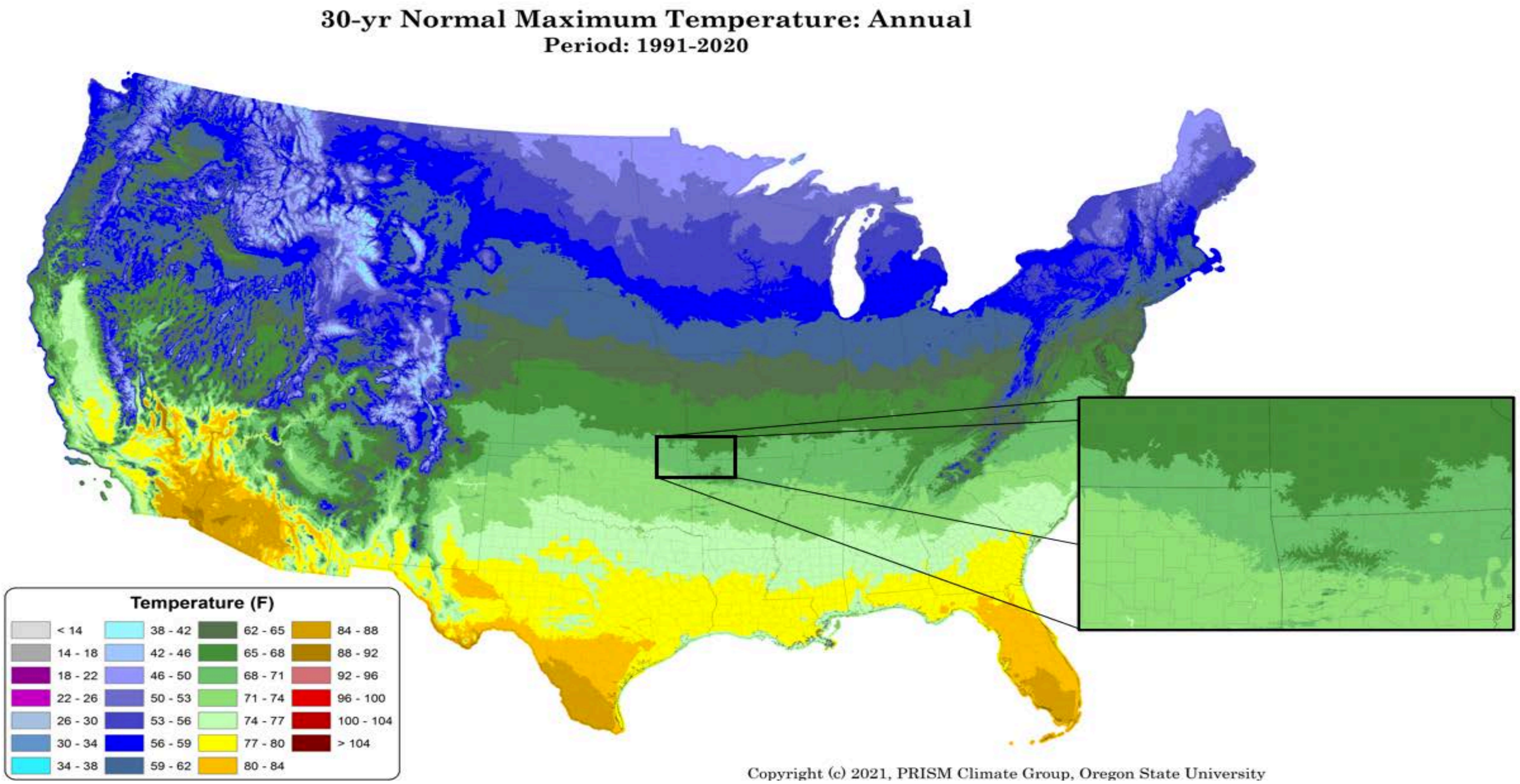


Figure 2-12. PRISM 30-year Normal Maximum Temperature Data (1991-2020)

The Climate Voyager Interactive Tool was used to understand future projections for temperature and precipitation within our planning range (to the year 2050). The online tool provides a summary of conditions from 20 climate models across four future 20-year time periods from 2020 to 2099 for a set of climate metrics. For each metric and location, the tool's summary graphic displays a bar showing the mean and spread of the results or change from present conditions from the 20 downscaled GCMs. The available and pertinent available metrics for understanding the overarching climate trends include summer precipitation, minimum temperature thresholds, and summer temperatures. Figure 2-13 through Figure 2-15 summarize the projected **changes** in these metrics, respectively, for the region. For each figure, the lighter bar on the left of each period represents the reduced/moderate emissions scenario (RCP 4.5) and the darker bar on the right represents the current/high emissions scenario (RCP 8.5).

Within this region, the overall trends are towards a wetter climate in the summer, which was typically on the drier side of the year for the region. The historic period mean was estimated at 11.5 inches for these three months and the future projections for the period encompassing 2050 show on average a doubling of the precipitation expected. The increase in precipitation is important to understand as it is a potential driver for increased runoff and, therefore, pollutant loads delivered to the lake.

With temperature, the projections show a warming climate with a decrease in the number of days below freezing and an increase in summer temperatures. Historically, the region experienced 84.1 days below freezing on average, while the average historic summer temperature was estimated at 76°F. The 2050 projections indicate approximately three weeks less of freezing temperatures and average summer temperatures around 82°F. Like wetter summers, with fewer days below freezing, there is a greater potential for transport processes leading to increased pollutant loadings to waterways.

To represent these projected climate changes, a set of scenarios examining the increase in temperatures (warm or hot) and comparisons between the predominately wetter seasonal rainfall expected (wet) and the less likely although likely impactful potential drier conditions (dry) were examined in the modeling conducted for the District (RTI International, 2022). These scenarios were based on the establishment of historically warm and hot/wet and dry month thresholds as compared to the projected future climate scenarios. The comparison of the historic to future conditions resulted in monthly adjustment factors that were applied to the historic climate record to develop four bounding climate scenarios: Dry and Hot; Dry and Warm; Wet and Hot; and Wet and Warm.

As shown in Figure 2-13, between 2040 and 2059 under the higher emissions scenario, projections show an increase in summer precipitation between 8 and 13.9 inches. All future scenarios show a projected increase greater than 4 inches for the lake region (Benton County). Visit the [Climate Voyager Interactive Tool]() to explore data for other counties in the region.

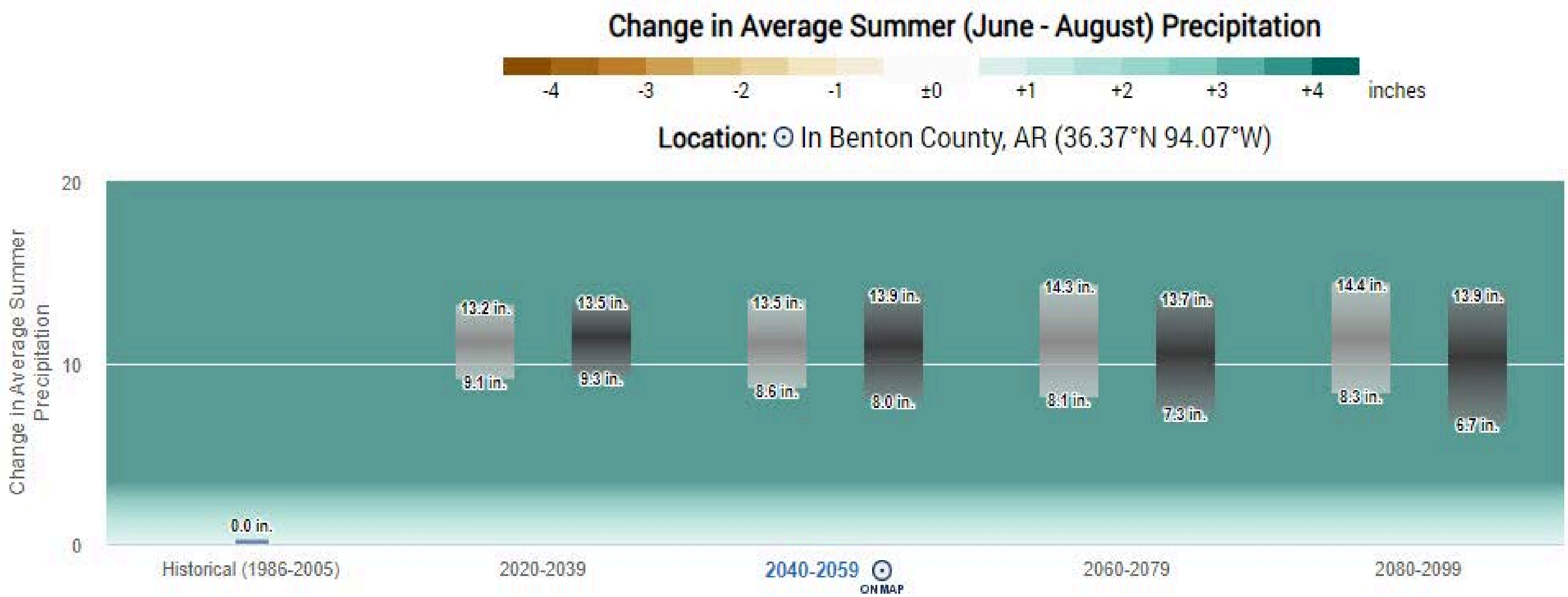


Figure 2-13. Change in Average Summer Precipitation based on Future Predictions for Benton County, Arkansas, using the Climate Voyager Interactive Tool.

As shown in Figure 2-14, between 2040 and 2059 under the higher emissions scenario, projections show between 10 and 40.3 fewer days with below freezing temperatures. All future scenarios show fewer days with below freezing temperatures for the lake region (Benton County). Visit the [Climate Voyager Interactive Tool] to explore data for other counties in the region.

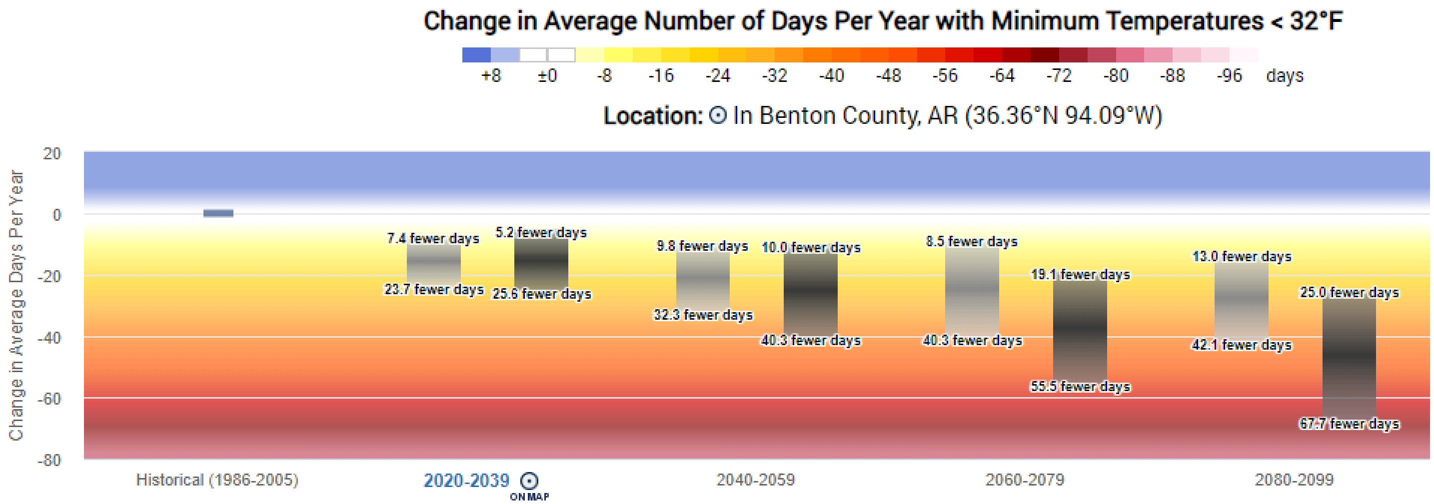


Figure 2-14. Change in Average Number of Days Per Year with Minimum Temperatures < 32ºF based on Future Predictions for Benton County, Arkansas, using the Climate Voyager Interactive Tool.

As shown in Figure 2-15, between 2040 and 2059 under the higher emissions scenario, projections show average summer temperatures to increase between 2.8 and 9.2°F. All future scenarios show average summer temperature increasing for the lake region (Benton County). Visit the Climate Voyager Interactive Tool to explore data for other counties in the region.

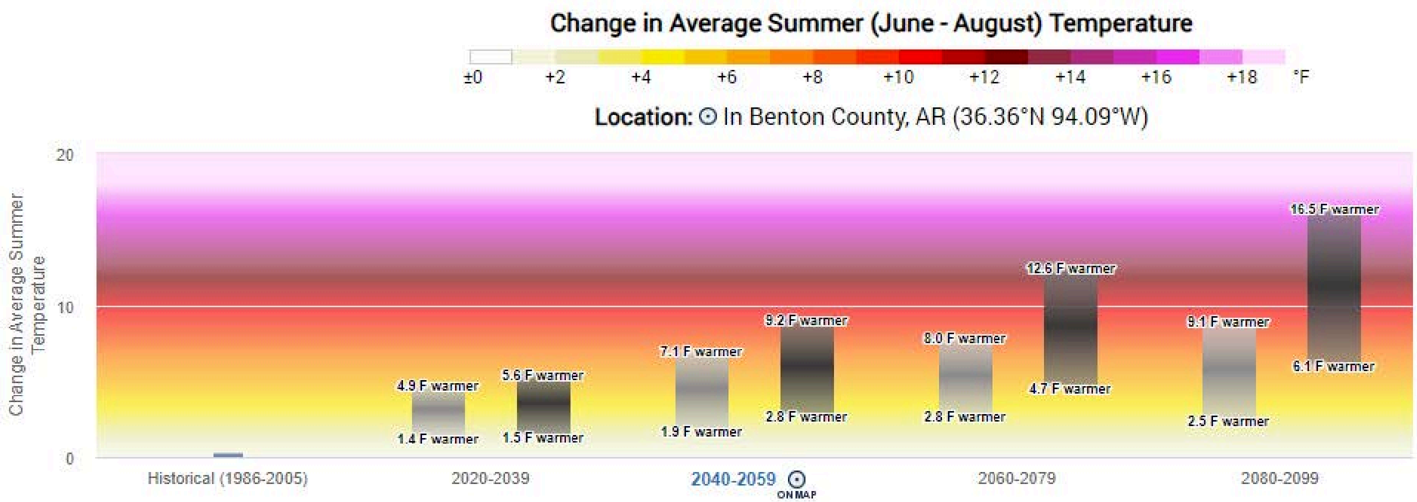


Figure 2-15. Change in Average Summer Temperatures based on Future Predictions for Benton County, Arkansas, using the Climate Voyager Interactive Tool.

2.2 Existing and Future Loads to the Lake

RTI conducted watershed-based modeling for the District using the Watershed Flow and Allocation model (WaterFALL®; Eddy, et al., 2017; Eddy, Lord, Perrot, Bower, & Peoples, 2022). This modeling allowed for the simulation of water quantity and quality at high resolution throughout the watershed under both current and projected future conditions at a daily time step for 15-year periods. With this resolution of modeling in space and time, an understanding of the locations and magnitudes of water quantity and quality concerns can be developed to prioritize locations for action (RTI International, 2022). This section of the report provides a brief introduction to WaterFALL, details on the model inputs pertaining to nutrient sources within the watershed pertinent to management, comparisons between the loadings derived within each subwatershed, and assessments of potential projected future changes in water quantity and quality that can be used to help prioritize local areas for taking action.

2.2.1 Watershed Modeling to Examine Loadings

A Note on Karst Topography

Due to the underlying karst topography in the region, RTI first sought data to locate and quantify sinks and springs. While there were data on spring locations, there was no comprehensive data to further define the impacts of those locations. RTI then used the calibration process against downstream streamflow gages to assess whether there were any identifiable trends missed within the modeling that could be attributed to springs or sinks. Because no trends were found, further assessment of karst topography on the surface water system across the watershed was not continued. However, it is acknowledged that the local impacts of karst topography should be considered when pursuing the watershed protection strategies characterized within this study.

WaterFALL is a semi-distributed rainfall-runoff model that simulates daily streamflows at the catchment resolution within NHDPlus version 2. Within NHDPlus, each catchment corresponds to one networked stream segment, allowing for the simulation of the local watershed contribution of flow and loadings of nitrogen, phosphorus, and sediment to each stream segment. Local streamflow and constituent loading contributions are then routed to estimate downstream cumulative streamflow and loads. Within each catchment, the land cover/use, soils, and subsurface are characterized. Coupling the catchment characteristics with daily estimates of temperature, precipitation, and any water uses (withdrawals or returns with accompanying constituent loadings) provides a stream segment-scale daily rainfall-runoff and baseflow simulation of streamflows and water quality.

WaterFALL includes the simulation of sediment, total nitrogen, and total phosphorus loadings from the surface and subsurface flows on a daily time step. Sources for these water quality constituents included within the model are background concentrations within the soils of rural areas, build up and wash off or runoff of sediment and nutrients from impervious developed areas, manure application over agricultural lands, septic systems, background groundwater concentrations, point sources within the stream network, and streambank erosion.

Manipulating the inputs around land use/cover, climate, water uses, and water quality inputs enables WaterFALL to simulate different potential future and/or watershed management scenarios impacts on local stream flows and water quality as well as cumulative inflows and loadings of nutrients and sediments to the reservoirs. Scenario-based modeling of water quality and quantity factors provides insights into the available water resources over an extended period for a variety of potential future conditions. The modeled future water quality and quantity in the baseline and alternative scenarios help to identify possible mitigation and resiliency strategies and evaluate their potential efficacy.

2.2.1.1 Model Inputs Related to Managed Sources

For a full accounting of model inputs, including calibrated loading rates, soil and groundwater concentrations, and other relevant input parameters, please see the report summarizing the work conducted for the District for identifying conservation priorities (RTI International, 2022).

Septic Systems

Septic tank locations were approximated using the Arkansas Highway and Transportation Department (AHTD; now the Arkansas Department of Transportation) rural building layer, assuming each rural building had one septic tank. This assumption was referenced from the District's Source Water Protection Plan (page 21) (Beaver Water District, 2018). This layer was then modified to account for the sewer lines present in the Fayetteville area. Referencing the "Sewer Basins" layer from the City of Fayetteville Utilities GIS Map, those rural buildings located within a "Sewer Basin" in the lower West Fork area were removed from the septic tank count. This modification removed 403 rural buildings from the layer, as it can be assumed those buildings are within the City of Fayetteville sewer network, and therefore not using a septic tank, resulting in the counts shown in Figure 2-16 (RTI International, 2022).

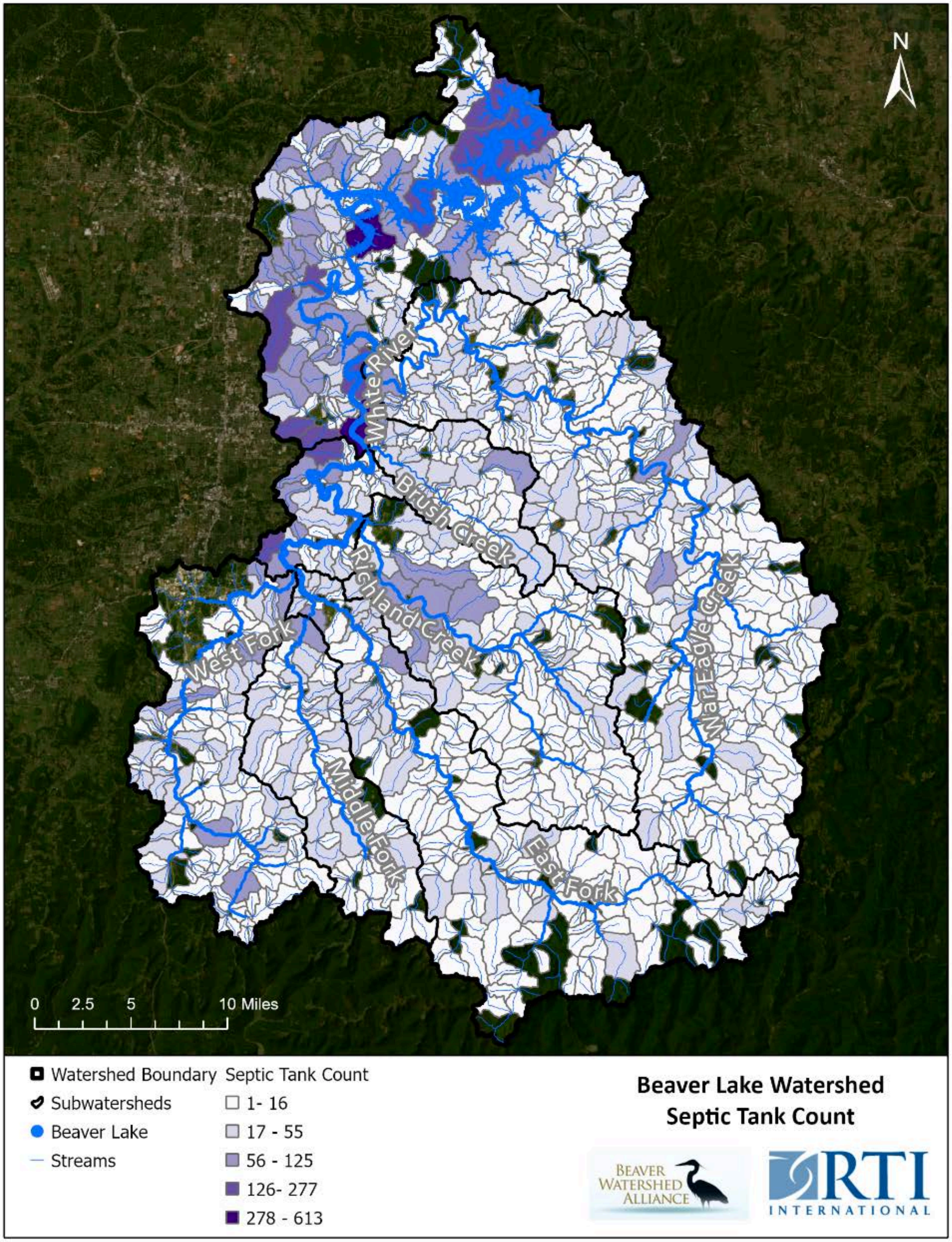


Figure 2-16. Estimated Septic Tank Count (as based on rural buildings) within each NHDPlus Catchment in the Beaver Lake Watershed

Manure Loads

Daily nutrients generated on pasturelands receiving manure were estimated based on the number of poultry houses within each NHDPlus catchment (Figure 2-17), the number of birds per poultry house, the assumed average weight per bird, and default values for daily nitrogen and phosphorus loads per animal equivalent unit (AEU). These assumptions are summarized below and consequently inform decision making for manure management plans by better understanding methods for identifying and quantifying sources of manure.

The number of poultry houses within each NHDPlus catchment was calculated based on the "Chicken House" layer obtained through the Arkansas GIS Office, and developed by AHTD. This layer was originally published in 2006 and last updated in 2014. To further update the layer, it was then modified using geospatial analysis to determine which poultry houses have since closed and were removed and which poultry houses are still in existence. This process is reliant upon the "Chicken House" layer from the AHTD office, and therefore might not represent poultry houses that were installed since the creation of the layer. This analysis was performed by adding a 30-meter (98.4 ft) buffer to the poultry house layer and selecting out those areas with an NLCD 2019 land cover of 21, 22, 23, and 24 (developed land cover types) as it was found that due to the size of the poultry houses they were represented in the NLCD as impervious and therefore developed land cover. A spatial join was then performed to find those poultry houses that intersected with the NLCD developed land cover types (Figure 2-18). Finally, the process was verified using 2021 satellite imagery (Figure 2-19). It is important to note that the poultry houses were confirmed as "current" if the rectangular-roofed building is still present in the satellite imagery; however, this method could not confirm that the operation is still active. Similarly, a poultry house was confirmed as "historic" if evidence of previous rectangular-shaped buildings appears in the satellite imagery. Figure 2-19 represents an example of this analysis, and Figure 2-17 represents the final best estimate of count of current poultry houses in the region per NHDPlus Catchment (RTI International, 2022).

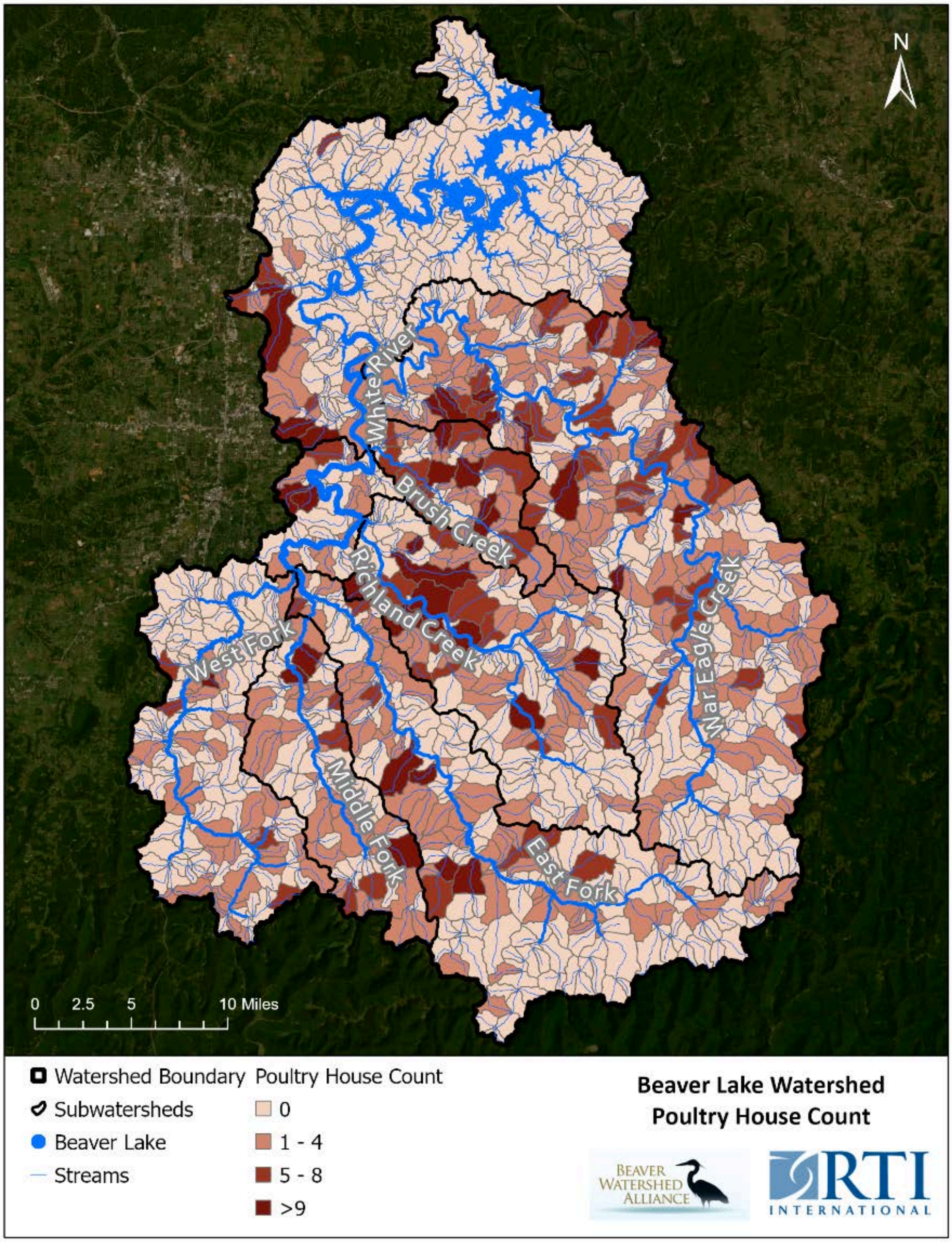


Figure 2-17. Estimated Count of Poultry Houses for each NHDPlus Catchment within the Beaver Lake Watershed

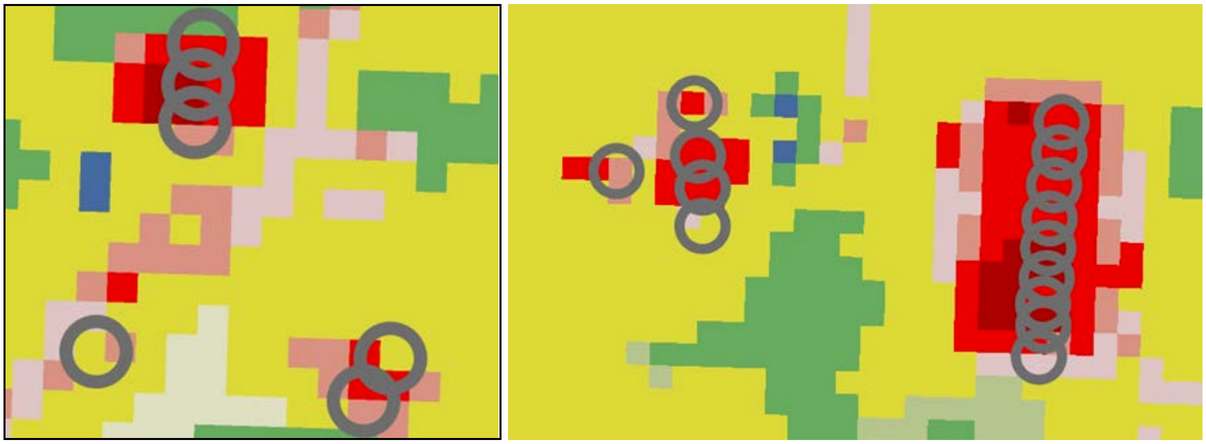


Figure 2-18. Examples of Current Poultry Houses Overlayed with the NLCD 2019 Land Cover. Poultry Houses are Represented by Gray Circles and Shades of Red Indicate Developed (NLCD 21, 22, 23, 24) Land Cover.

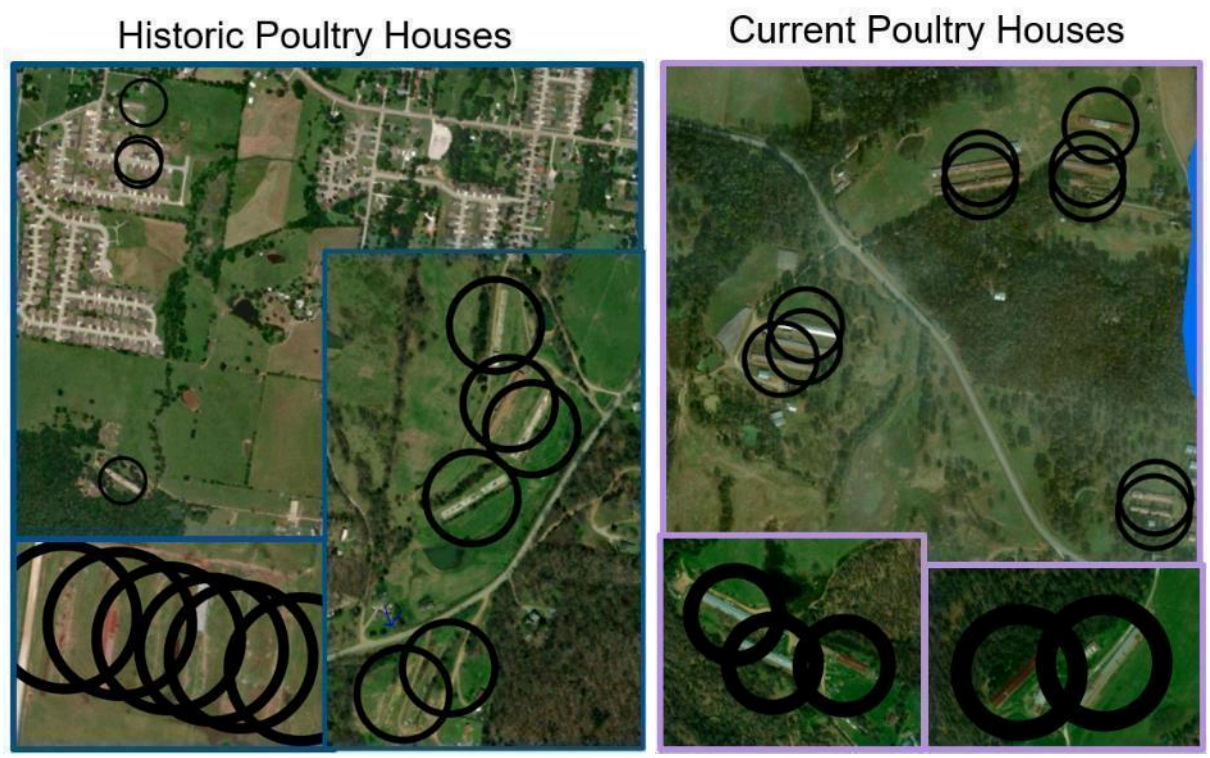


Figure 2-19. Examples of Historic (left) and Current (right) Poultry Houses. From AHTD Chicken House Layer and Identified Using the NLCD-based GIS Analysis.

To model the load per bird, an average of 30,000 birds per chicken house was assumed based on the approximate range of 20,000 to 40,000 birds per house provided by District Conservationist, Josh Fortenberry. A default value of 1.98 lbs (0.9 kg) was used for average weight of waste per bird for broilers.

Daily concentrations of nutrients lost to surface water from manure applied to agricultural land were estimated during the spring season, from March through June. Manure application starts in early spring. However, wet conditions following precipitation limit manure application. Therefore, a rain threshold of 0.1 cm (0.039 in) was applied. For each day within the spring season where the precipitation is less than 0.1 cm (0.039 in), WaterFALL accounts for a loading of nitrogen and phosphorus from manure applied to agricultural land. The buildup of nutrients from manure within the surface sediments is based on the daily nutrient rate (tons/d) applied on pastureland, an assumed depth of manure spread, the area of the pastureland, and the average soil bulk density. These assumptions are summarized in the District's Conservation Assessment Report (RTI International, 2022). The daily nutrient manure loads generated in each catchment within the watershed represent the priorities for manure management for animal operations and are mapped in Figure 2-20 and Figure 2-21. This buildup of nutrients is then available for wash-off sediment during runoff-generating events.

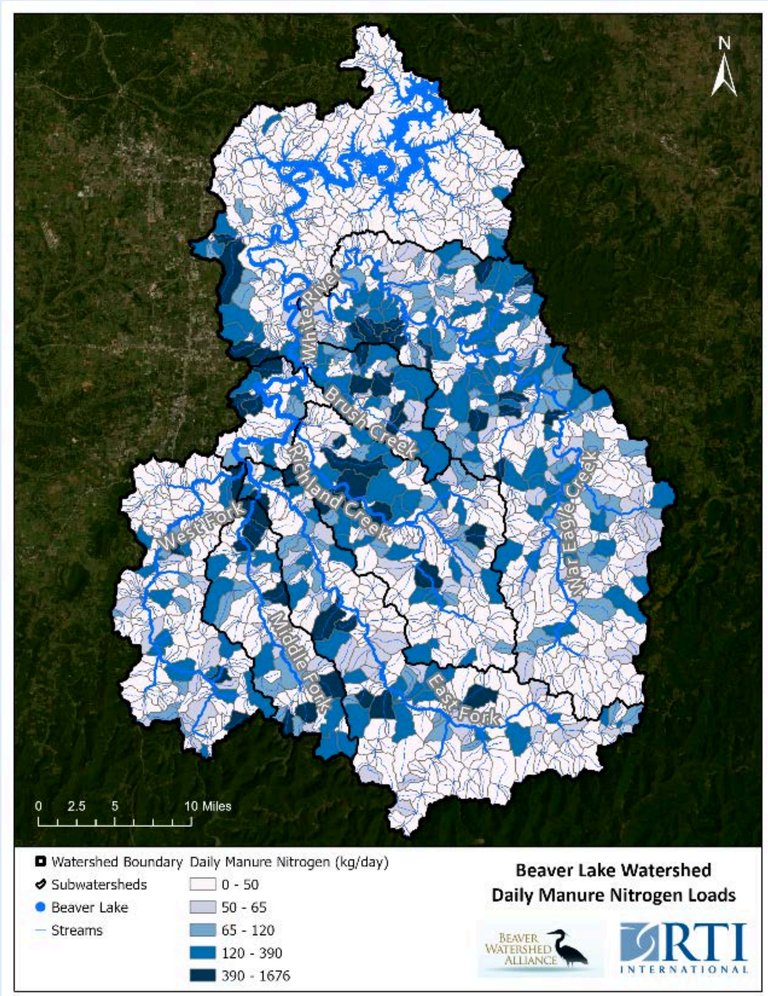


Figure 2-20. Estimated Daily Manure Nitrogen Loads to Pastureland within each NHDPlus Catchment in the Beaver Lake Watershed.

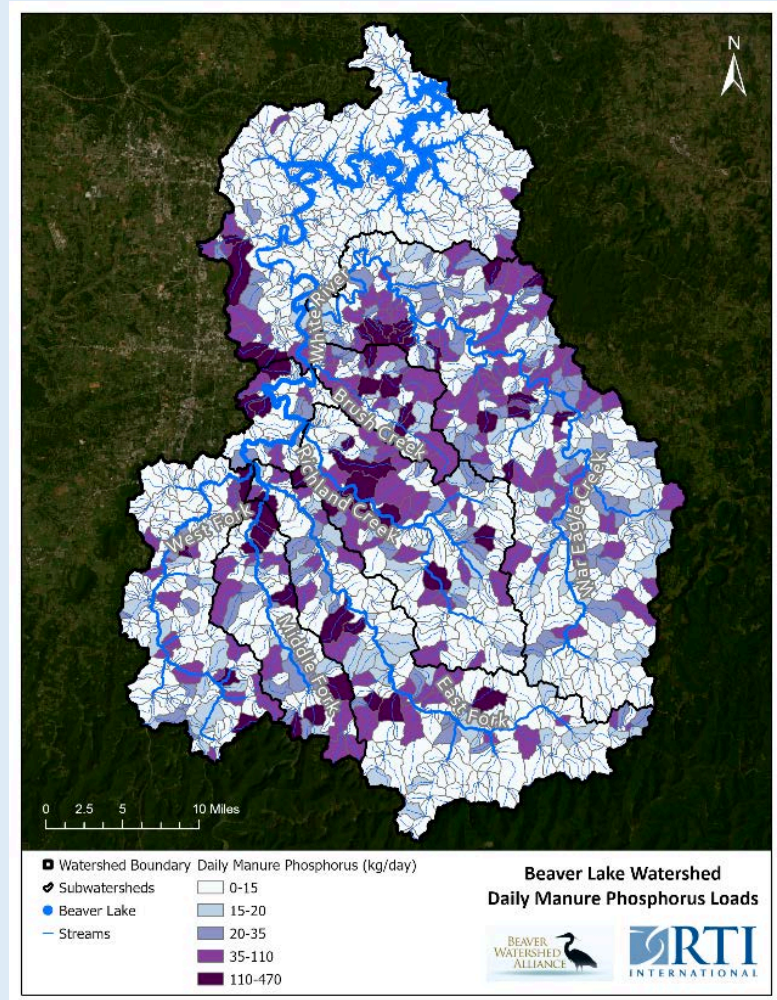


Figure 2-21. Estimated Daily Manure Phosphorus Loads to Pastureland within each NHDPlus Catchment in Beaver Lake Watershed.

Streambank Erosion

Streambank erosion was included in the model using conservative estimates of the load resulting from the in-channel erosion as well as for the locations and severity of the issue throughout the watershed. Therefore, in lieu of discussing the methods and inputs included in the model, the reader is directed to Section 4.2.2.3.

Rock Creek, tributary to the West Fork - White River, prior to restoration work.

Point Sources

There are three National Pollutant Discharge Elimination System (NPDES)-permitted facilities within the watershed with measured discharges of sediment, nitrogen, and phosphorus (Table 2-2). Using EPA's Enforcement and Compliance History Online (ECHO) tool to access Discharge Monitoring Reports (DMRs) for each year, the discharged load for each of the three permits for total suspended solids (TSS), total phosphorus (TP), and ammonia as nitrogen (NH4asN) were obtained. Records for the years 2014-2018 were not of similar orders of magnitudes and trends and as such were removed for quality control (Figure 2-22).

Table 2-2. Point Source Discharges within Beaver Lake Watershed

NPDES Permit No.	Facility Name	Receiving Water	NHDPlus COMID	Design Flow (MGD)	Actual Average Flow (MGD)	Residents Served	NPDES Class
AR0022004	Huntsville WWTP	Town Branch of Holman Creek (War Eagle)	8588734	2.0	1.95	1,931	Major
AR0020010	Fayetteville – Noland WWTP	White River	8590894	12.6	5.26	38,921	Major
AR0022373	City of West Fork*	West Fork White River	8592244	0.1	0.14	1,042	Non-Major

Note: *The City of West Fork was connected to the City of Fayetteville's wastewater system in 2021.

As communicated by the District, the City of Fayetteville (AR0020010) has kept the phosphorus discharge from the Noland Wastewater Treatment Plant (WWTP) very low. For most years, this WWTP discharges less than 4,000 lbs of phosphorus to the White River, whereas they are permitted ten times that amount. There has also been a large drop in phosphorus load from the City of Huntsville over the last 10 years, while there has been a small increase in the nitrogen being discharged as ammonia from the City of West Fork in the most recent years (Figure 2-22).

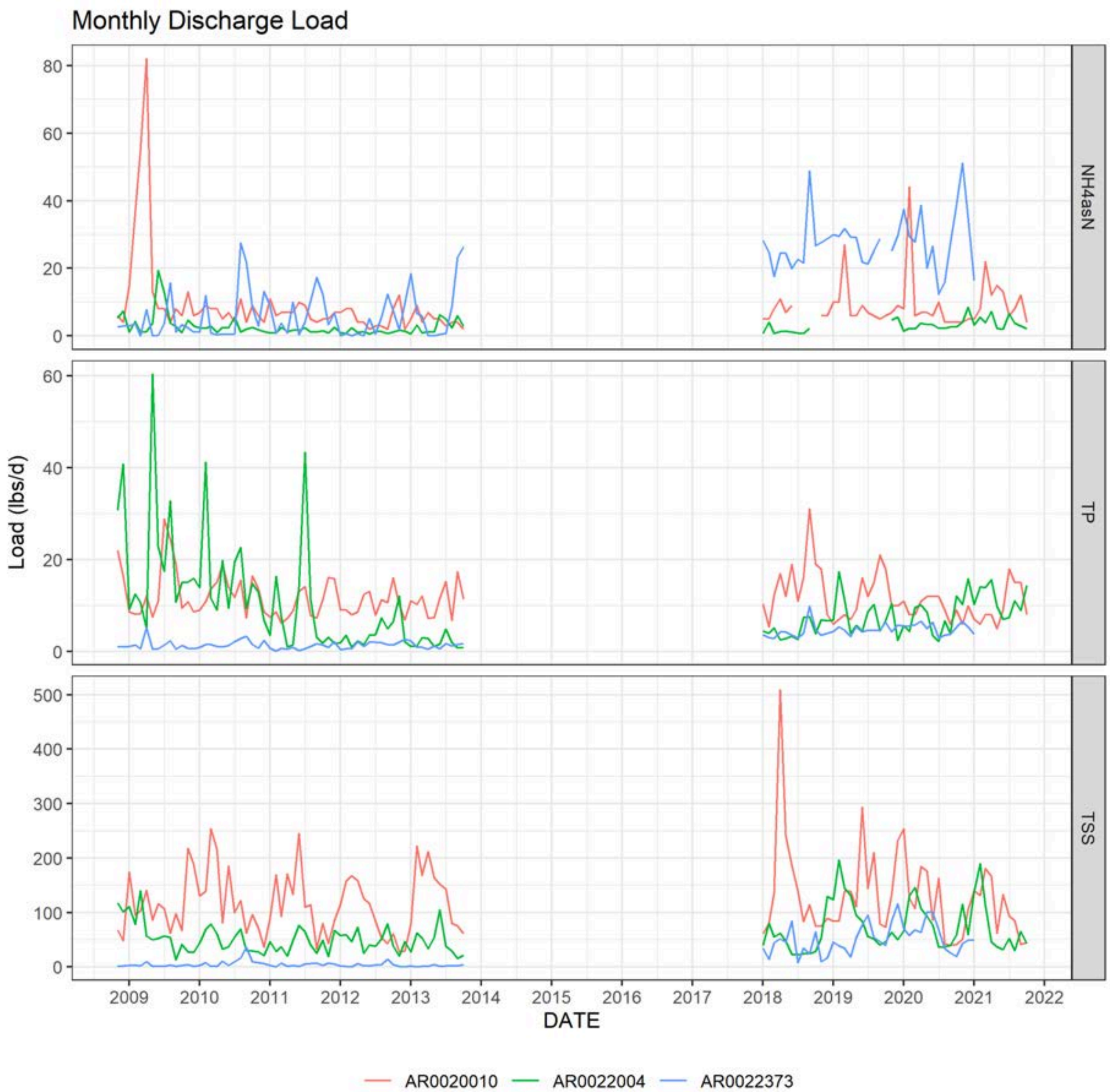


Figure 2-22. Monthly Estimated Pollutant Discharge Loads for the Three Permitted Facilities within Beaver Lake Watershed.

2.2.1.2 Model Performance and Scenario Analysis

Calibration of the model for hydrology and water quality was completed at five locations representing the downstream ends of the main tributaries within the watershed (RTI International, 2022). Qualitative measures of the model performance for the hydrologic simulations reveal a well performing model that generally captures the hydrologic regime and the annual and monthly trends, although there is some slight underestimation of peak flows and extreme events. Quantitative performance metrics show the model attaining the criteria for “very good” performance (according to standards within watershed modeling literature) for four out of the five gages for percent bias in flow volume, with Richland Creek, which was listed as having poor record quality and impact from backflow, only slightly missing that criterion (±10%) with a percent bias (PBIAS) of -13%. A similar breakdown in performance was shown in the Monthly Nash-Sutcliffe Efficiency (NSE), with all gages except Richland Creek having values of 0.83 or more (Richland Creek had a monthly NSE of 0.64). Daily performance statistics were lower due for all gages due to the peak flow events and several gages with observed daily streamflows dropping to zero. With acceptable model simulation performance shown for hydrology, water quality was then simulated.

To calibrate and assess the performance of the water quality simulation, several graphical techniques were used including comparisons of the long-term distribution and interquartile range of daily loads, daily comparison of observed versus simulated load, and the relationship between streamflow and load (RTI International, 2022). Each of these comparisons was done for the five subwatershed outlets with observation gages. The distributions of daily loads of sediment showed that long-term median daily loads were estimated well by the model as were the interquartile ranges, which spanned several orders of magnitudes. The model diverged the most from the observations when comparing the peak daily loadings (shown as outliers to the distributions (RTI International, 2022) and as seen in the differences in model performance between daily average (mean) and median loads (Table 2-3).

The peak loads correspond to high precipitation events and were most prevalent in War Eagle Creek and Richland Creek, although there were peak loads simulated beyond the observed loads in all subwatersheds. There were only three sample observations that corresponded to the identified peak flow events in the 15-year record and those observations were made for the other three gages with less prevalent outliers. There is evidence that these peak loads are in fact reasonable as there were corresponding spikes in the turbidity at the District’s intake for those storm days. Due to these large events, the long-term mean annual total loadings to Beaver Lake from each subwatershed are higher than in previous studies.

Table 2-3. Summarized Daily Modeled and. Observed Average (Mean) and Median Streamflow and Loads for Total Suspended Sediment (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) at four Stream Gages in Beaver Lake Watershed from 2007 to 2020

Name	Statistic	Streamflow (cfs)		TSS (US tons)		TN (US tons)		TP (US tons)	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median
West Fork 07048550	Modeled	202	88	198	1.1	0.5	0.13	0.31	0.004
	Observed	211	55	260	1.2	1.1	0.09	0.34	0.005
White River 07048600	Modeled	668	315	459	3.7	1.4	0.44	0.96	0.013
	Observed	632	198	600	4.5	2.5	0.27	0.61	0.018
Richland Creek 07048800	Modeled	168	70	295	0.62	0.51	0.09	0.69	0.002
	Observed	177	44	141	0.31	1.1	0.17	0.40	0.003
Brush Creek 07048890	Modeled	29	7	145	0.06	0.17	0.01	0.31	0.0002
	Observed	29	7	47	0.05	0.25	0.07	0.07	0.001
War Eagle Creek 07049000	Modeled	351	138	821	1.5	1.1	0.19	1.1	0.005
	Observed	398	111	239	1.1	3.1	0.49	0.50	0.009

Note: Water quality observations were only available through 2020 at the time of analysis; therefore, this comparison is across a 14-year period rather than the 15 years of the full baseline scenario.

Once the model was calibrated for hydrology and water quality at the available sites, WaterFALL was used to simulate the potential projected future conditions and the mitigation of riparian pasturelands (RTI International, 2022). The series of scenarios are used to assess (1) the impacts of projected land use change due to urbanizing lands in the west outside Fayetteville and the development of former pasturelands into residential communities; and (2) the impacts of potential climate changes. All scenarios were run for a 15-year period (Water Years 2007 through 2021). The future land use scenario was based on the 2050 ICLUS projection with rules regarding baseline 2019 NLCD. The future projected climate scenarios were selected as the four "bounding" scenarios to encompass the range of projected climate changes related to temperature and precipitation.

2.2.2 Comparisons Among Subwatersheds

Modeling of the watershed for the last 15 years (baseline scenario) revealed a wide range of annual loads for each subwatershed and between each subwatershed, as shown in Table 2-4. The wide range in annual sediment and nutrient loads is due to a few peak events in some years. Overall, the loads are higher in White River and War Eagle, as these subwatersheds have larger drainage areas and discharges. War Eagle Creek is estimated to provide the largest loadings of sediment, nitrogen, and phosphorus due to larger consistent low and average conditions loads and several large storm loading events each year. The loadings for the White River are in line with measured and estimated annual and storm loads and concentrations presented in the *2004 West Fork White River Watershed Data Inventory and Nonpoint Source Pollution Assessment* (Arkansas Department of Environmental Quality, 2004). For a discussion and analysis of the sources of these loads and mitigation strategies, see Section 4.2.2.

Table 2-4. Annual Average (Mean) and Range (Minimum and Maximum) Total Sediment and Nutrient Loads to Beaver Lake for Baseline Scenario (Water Years 2007-2021) from the Waterfall Model*

Inflow Subwatershed	Statistic	Sediment (US tons/yr)	Total Nitrogen (US tons/yr)	Total Phosphorus (US tons/yr)
White River	Mean Range	164,700 (28,950 – 389,970)	510 (130 – 960)	330 (7 – 710)
Richland Creek	Mean Range	119,840 (17,340 – 253,340)	200 (41 – 370)	250 (2.2 – 550)
Brush Creek	Mean Range	62,970 (5,680 – 161,440)	80 (11 – 180)	150 (0.7 – 530)
War Eagle Creek	Mean Range	370,420 (58,690 – 920,180)	520 (120 – 1,090)	520 (6.8 – 1710)

*Note: These were adapted from Table 7-5 in RTI's modeling report for the District, and any difference are likely from unit conversion and rounding values.

The baseline scenario daily sediment loads at the outlet of each subwatershed are shown in Figure 2-23. These loads are accumulations of the land-derived loadings, contributions from groundwater/baseflow, and the conservative estimates of streambank erosion. The daily loads highlight several large storm events each year, especially in War Eagle Creek, that contribute to the estimated annual total sediment loads. There were storm events in May 2011 and December 2015 that produced extreme flows and extreme sediment loads to Beaver Lake. These storms varied in intensity across the watershed. In addition to the two highlighted storms, additional storm loading events occurred in March 2008, October 2009, April 2011, May 2017, October 2020, and April 2021. In each of these events, there was at least one if not two, or in the case of the December 2015 storm, three days with loads over 99,000 U.S. tons in a single day. These isolated events are enough to drastically increase the annual total load and, as such, the annual average total loads delivered to the lake. Therefore, extreme events should be of concern in the future, particularly as the resulting sediment loads lead to higher levels of turbidity in the District's intake. For instance, the peak flow and sediment loading days of the

March 2008 storm (the 20th and 21st), with loads of 171,918 and 108,441 U.S. tons respectively, corresponded to peak turbidity recorded in the raw water at the intake with levels of 450 and 370 NTU, respectively. All these identified events, except for the October 2020 event, had observed peak turbidity levels of at least 150 nephelometric turbidity units (NTU) at the intake. The highest observed value at the intake occurred on April 28, 2011, at a level of 660 NTU. With the projected future wet climate scenarios shown, these events are expected to increase in frequency and duration leading to higher treatment costs for the District.

Figure 2-24 displays the generation of sediment across the watershed by catchment. The generation rate is divided by the area of the catchment to provide a normalized measure that can be directly compared across the watershed. This map shows that the largest areas of land-derived sediment loading generation are within Brush Creek, War Eagle Creek, and the western side of the final reaches of the White River before entering the lake. There are other localized areas of high generation. These areas have a mixture of agricultural and urban land covers and occur in areas with lower available water capacity in the subsurface (RTI International, 2022) allowing for more stable flows that constantly contribute baseflow loadings in addition to wash off from the surface. In War Eagle Creek, these areas have the highest loadings of nitrogen (Figure 2-25) and phosphorus (Figure 2-26) from manure in the watershed due to higher densities of poultry houses. It is important to note these maps mainly represent land-derived loadings, with additional loadings expected for areas of streambank erosion not fully captured within the modeling.

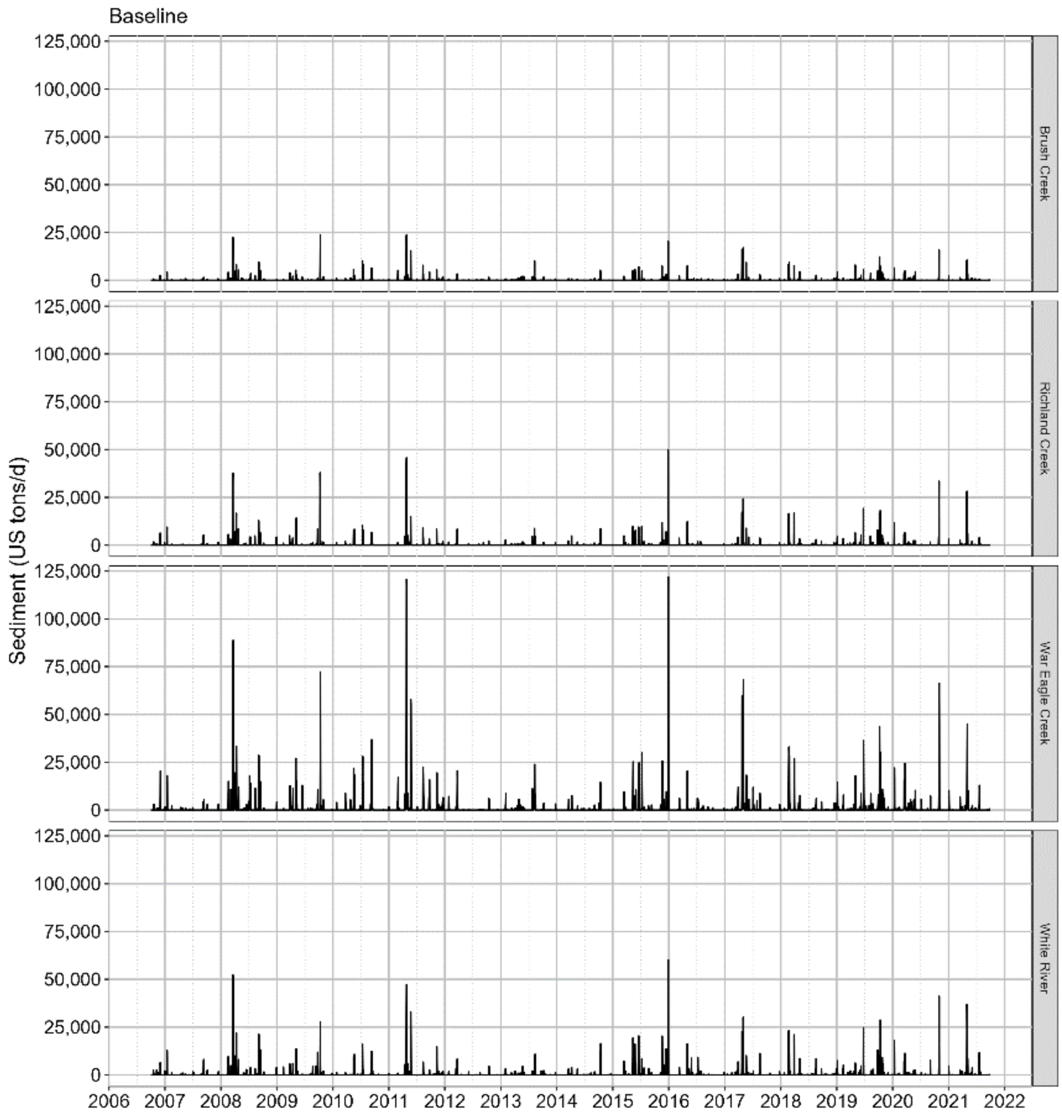


Figure 2-23. Daily Estimated Sediment Load at the Outlet of Each Subwatershed Entering Beaver Lake for the Baseline Scenario (Water Years 2007-2021)

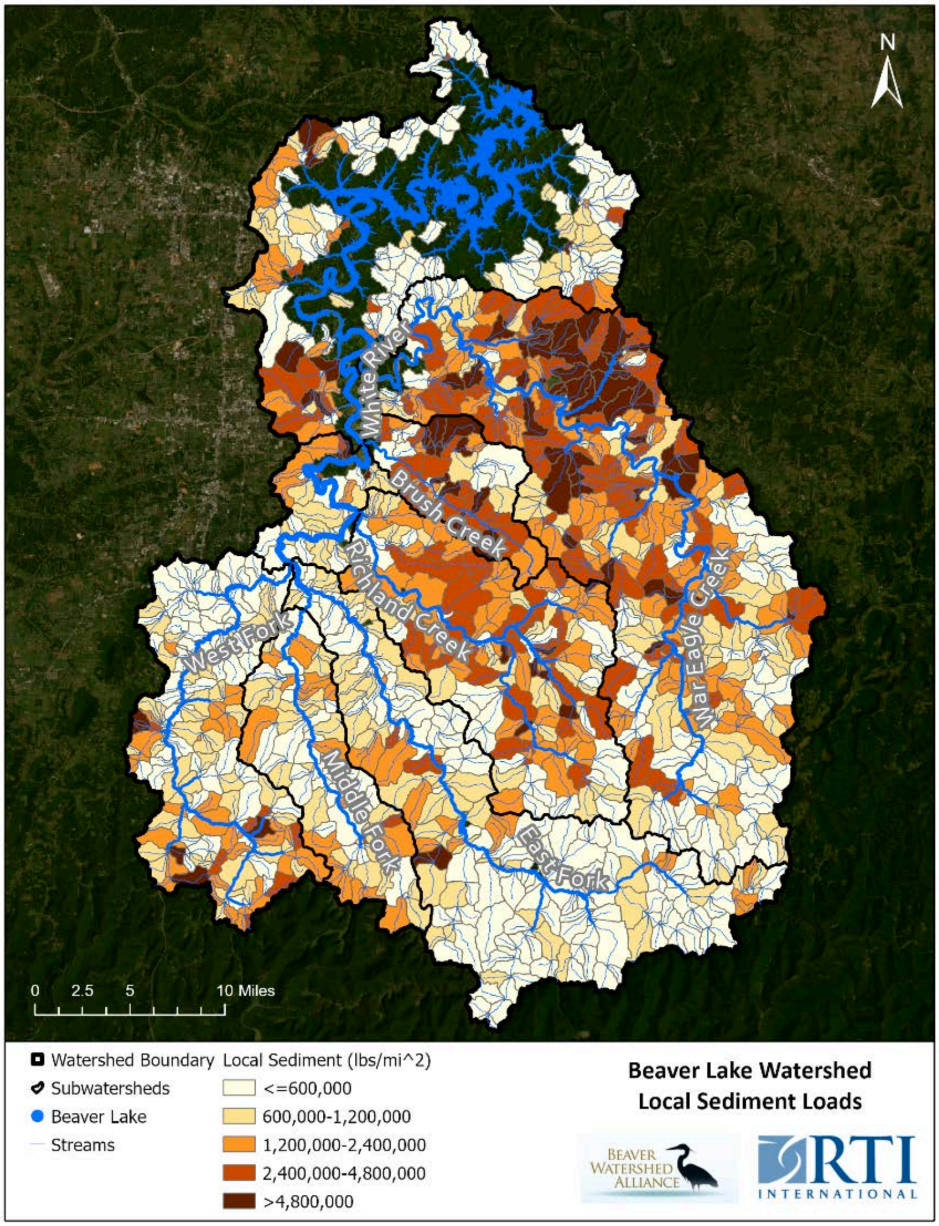


Figure 2-24. Estimated Average (Mean) Sediment Load Generated in Each NLDPlus Catchment Normalized by Area across the Beaver Lake Watershed.

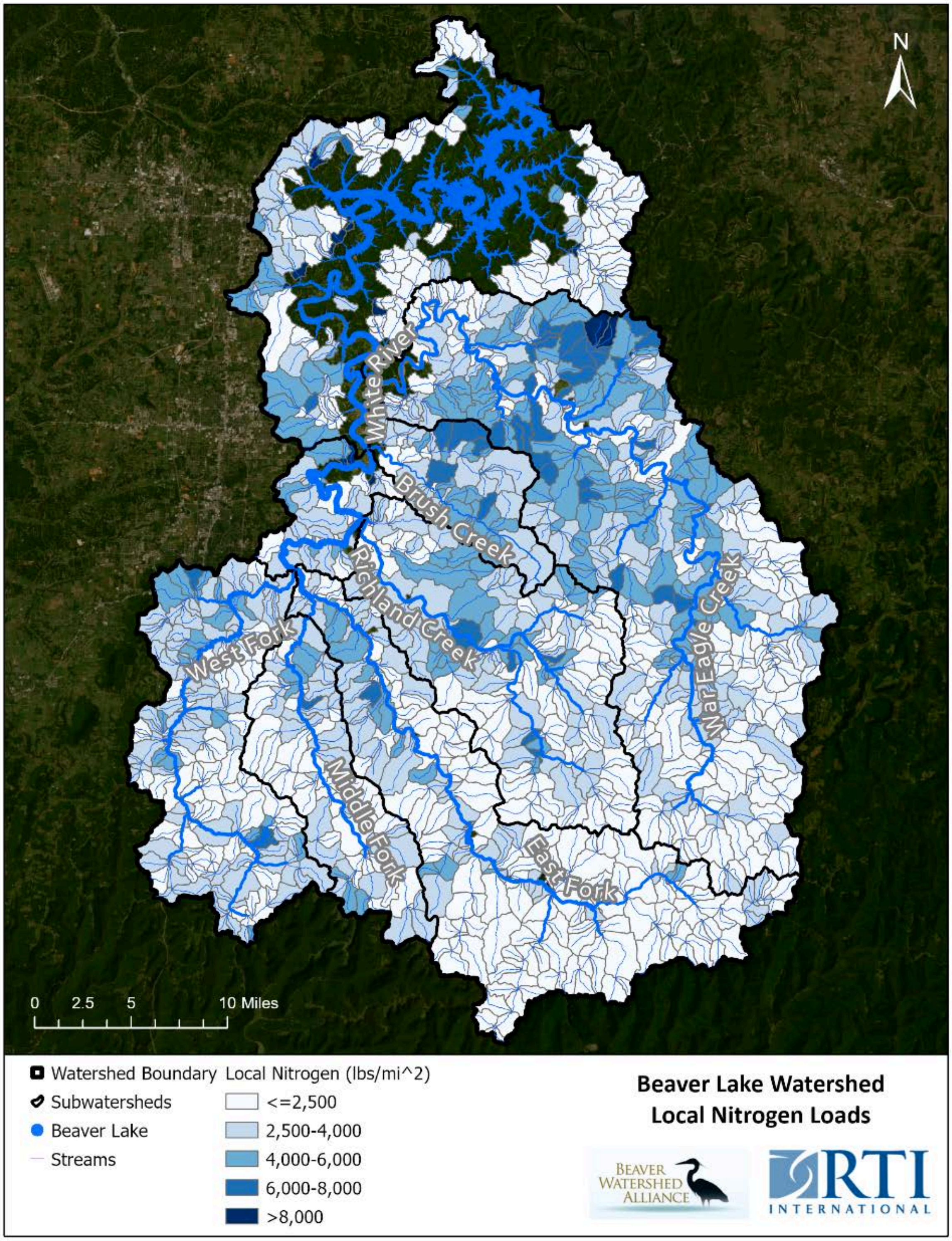


Figure 2-25. Estimated Average (Mean) Nitrogen Load Generated in Each NLDPlus Catchment Normalized by Area across the Beaver Lake Watershed.

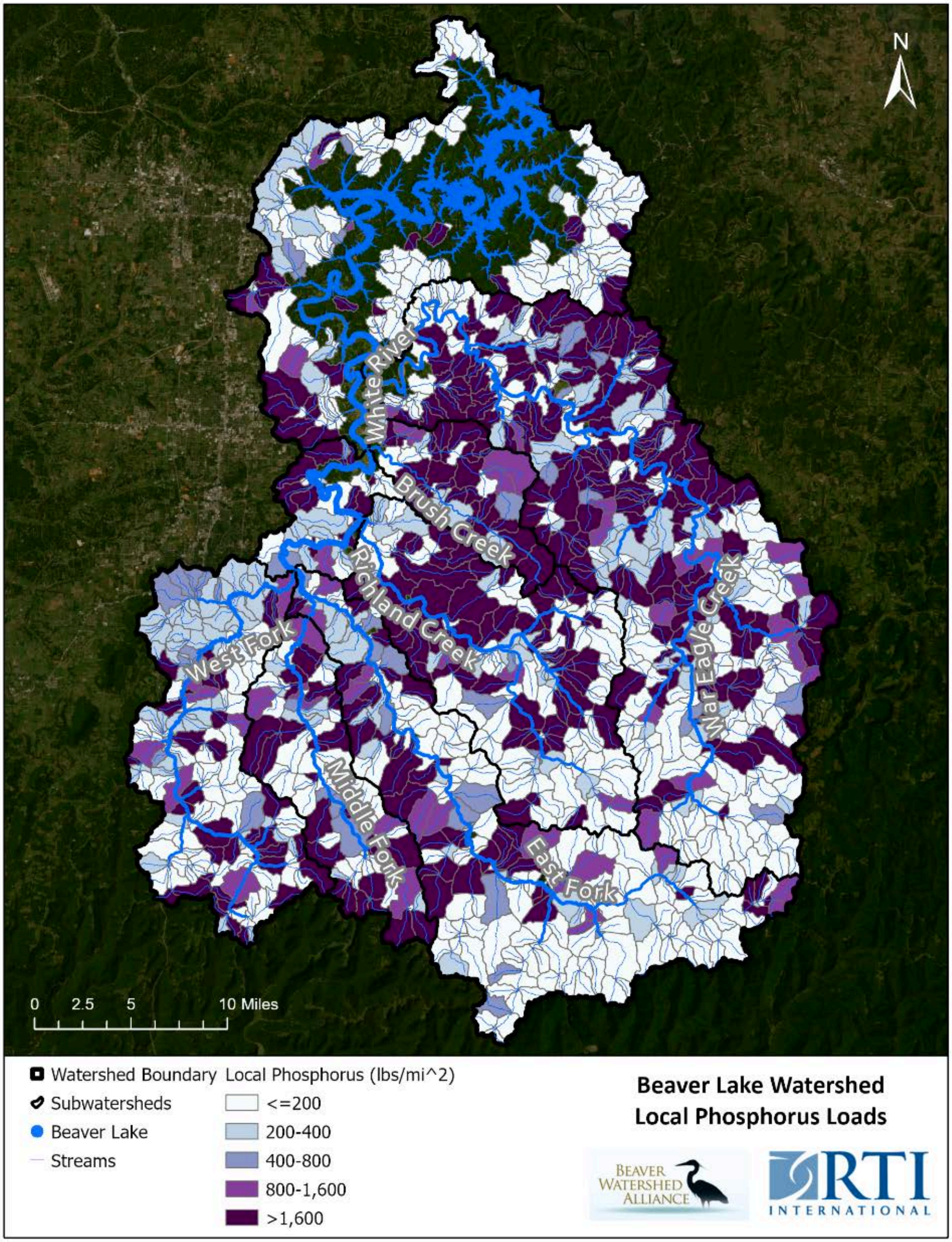


Figure 2-26. Estimated Average (Mean) Phosphorus Load Generated in Each NLDPlus Catchment Normalized by Area across the Beaver Lake Watershed.

2.2.3 Accumulation of Loads Through the Network

To help highlight source areas within each subwatershed and tributary, the cumulative loads of sediment, nitrogen, and phosphorus are shown longitudinally from headwaters to Beaver Lake. Rather than by distance, the average time of travel for each catchment to reach the lake is used as the longitudinal metric (Figure 2-27). Steadily increasing loads show a relatively constant source of sediment and nutrients from land areas across the subwatershed and along the downstream gradient of each tributary. Large “steps” in the modeled curve suggest major load contributions, which may show a localized source like streambank erosion, a point source, influence from a tributary, or a change in watershed conditions resulting in larger contributions. Across the White River (Figure 2-28), the lower tributaries (Figure 2-29), and War Eagle Creek (Figure 2-30) have the most “steps” whereas the biggest “steps” are seen within Middle Fork White River, West Fork White River, and Richland Creek. These steps can all be correlated with locations where streambank erosion has been observed. Within War Eagle Creek, the largest “steps” occur between a travel time of 40 hours and 0 hours at the subwatershed outlet. These steps correspond to the areas of greater sediment and nutrient loadings due to the pasture lands and manure application crossed with a greater frequency of high flow pulses and therefore runoff.

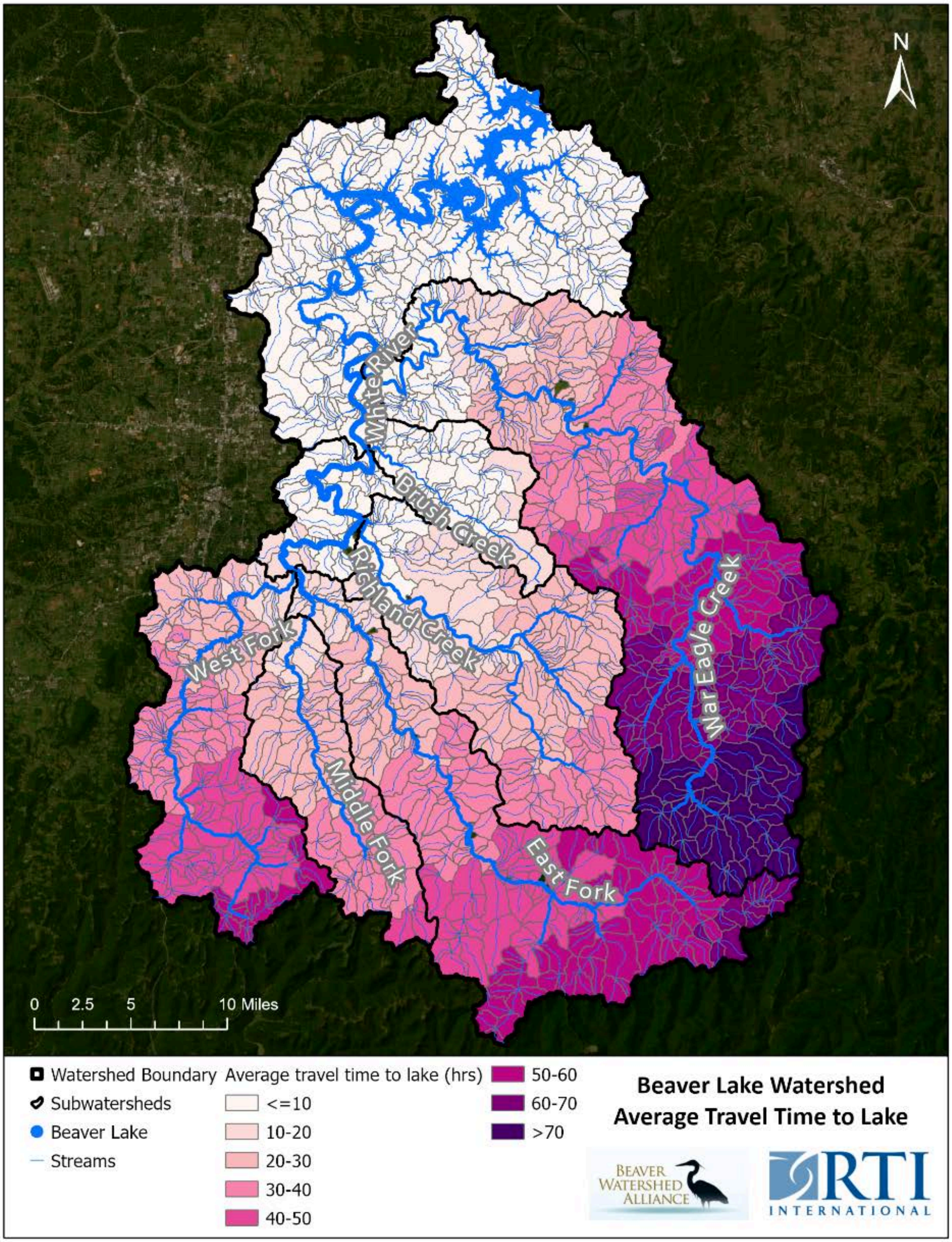


Figure 2-27. Average Time of Travel for Each Stream Reach across Subwatersheds to Beaver Lake.

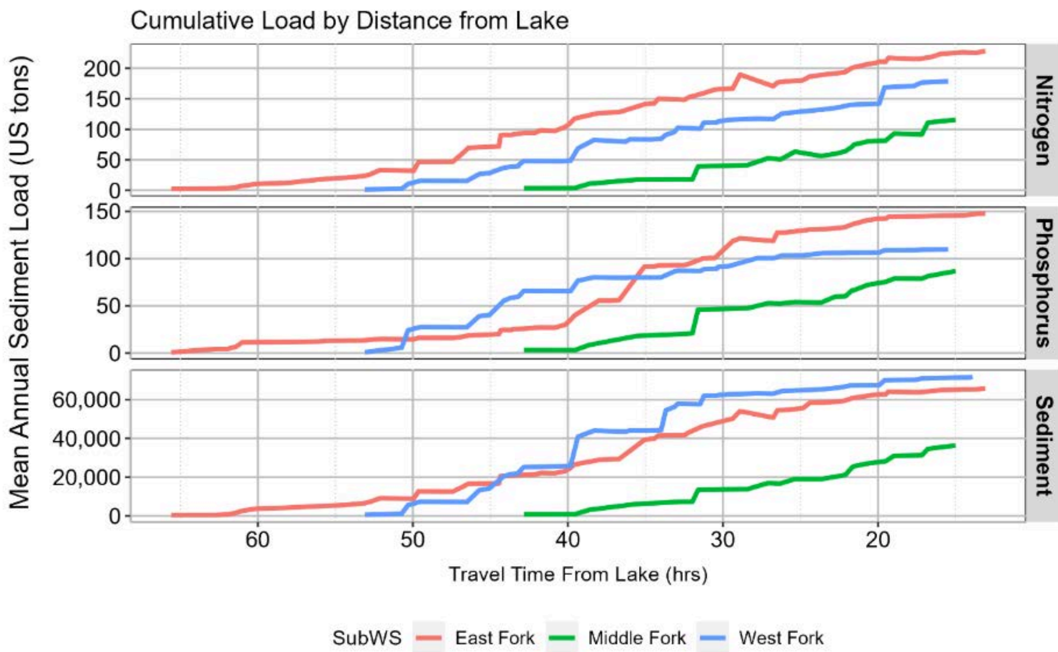


Figure 2-28. Accumulation of Sediment and Nutrient Loads based on Travel Time through the Tributaries of the White River to Beaver Lake.

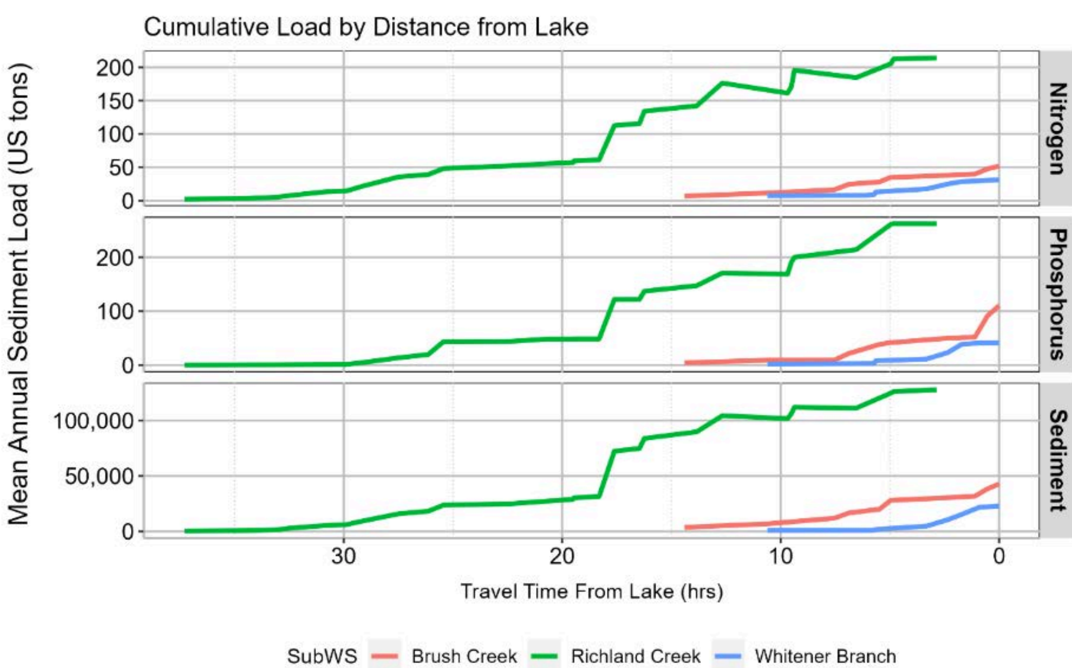


Figure 2-29. Accumulation of Sediment and Nutrient Loads based on Travel Time for Brush Creek, Richland Creek, and Whitener Branch to Beaver Lake.

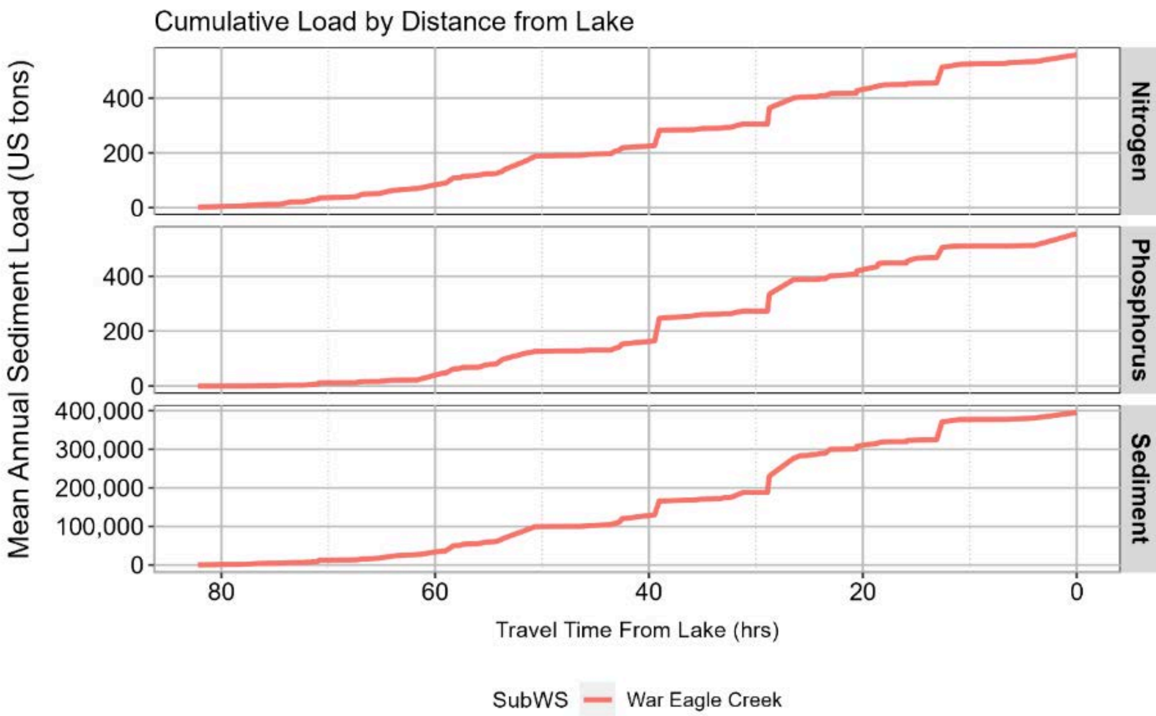


Figure 2-30. Accumulation of Sediment and Nutrient Loads based on Travel Time for War Eagle Creek to Beaver Lake.

2.2.4 Changes into the Future

The modeled flows and sediment and nutrient loads from the four future climate scenarios (Section 2.1.3)—Wet Warm, Dry Warm, Dry Hot, and Wet Hot—are shown in Table 2-5. The Wet Warm scenario has the highest average annual flow, average daily flow, and sediment and nutrient loads.

All scenarios are run for 15 years, although the future years are perturbations of the Baseline 15-year period. Figure 2-31 displays the annual average inflow to Beaver Lake by future climate scenario and the Baseline scenario for comparison. The future scenarios with a wet climate are more influential, showing large increases in high flow years. Temperature plays a lesser role where the differences between the warm and hot scenarios is much less than the differences between the wet and dry scenarios.

Within these future scenarios, the changes to peak, average, and low flows across the subwatersheds are visualized through flow duration curves in Figure 2-32. White River and War Eagle Creek follow the same general trends as in the Baseline scenario, with White River exhibiting a slightly flashier regime with higher peak flows and lower baseflows. However, in the Dry Hot and Dry Warm scenarios, the baseflows in White River are significantly lower than the baseflows in War Eagle Creek. In these two scenarios, White River, Brush Creek, and Richland

Creek all have low flows that are simulated as less than 0.1 cubic feet per second (cfs). In the Wet Hot and Wet Warm scenarios, all four subwatersheds follow similar trends as the Baseline scenario, although the low flows at Richland Creek are higher, but still under 0.1 cfs.

The annual average sediment, nitrogen, and phosphorus loads for each of four future climate scenarios by subwatershed are shown in Figure 2-33. War Eagle Creek has the highest average annual loads for all three parameters. The range in average annual loads is also largest in War Eagle Creek across all four scenarios except the range of nitrogen loads is larger at White River for the Wet Hot and Wet Warm scenario.

Table 2-5. Modeled Baseline Flows and Average (Mean) Annual Sediment, Nitrogen, and Phosphorus Loads from the Major Tributaries to Beaver Lake with Directional Change (i.e., Increases ↑ or Decreases ↓) for the Future Climate Scenarios.

Scenario	Average Annual Flow (cfs)	Average Daily Flow (cfs)	Mean Sediment Load (US tons/yr)	Mean Nitrogen Load (US tons/yr)	Mean Phosphorus Load (US tons/yr)
Baseline	486,730	360	717,850	1,312	1,245
WetWarm	Increase ↑	Increase ↑	Increase ↑	Increase ↑	Increase ↑
DryWarm	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓
DryHot	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓
WetHot	Increase ↑	Increase ↑	Increase ↑	Increase ↑	Increase ↑

Note: These total loads do not include the direct drainage for Beaver Lake nor Brush Creek subwatershed.

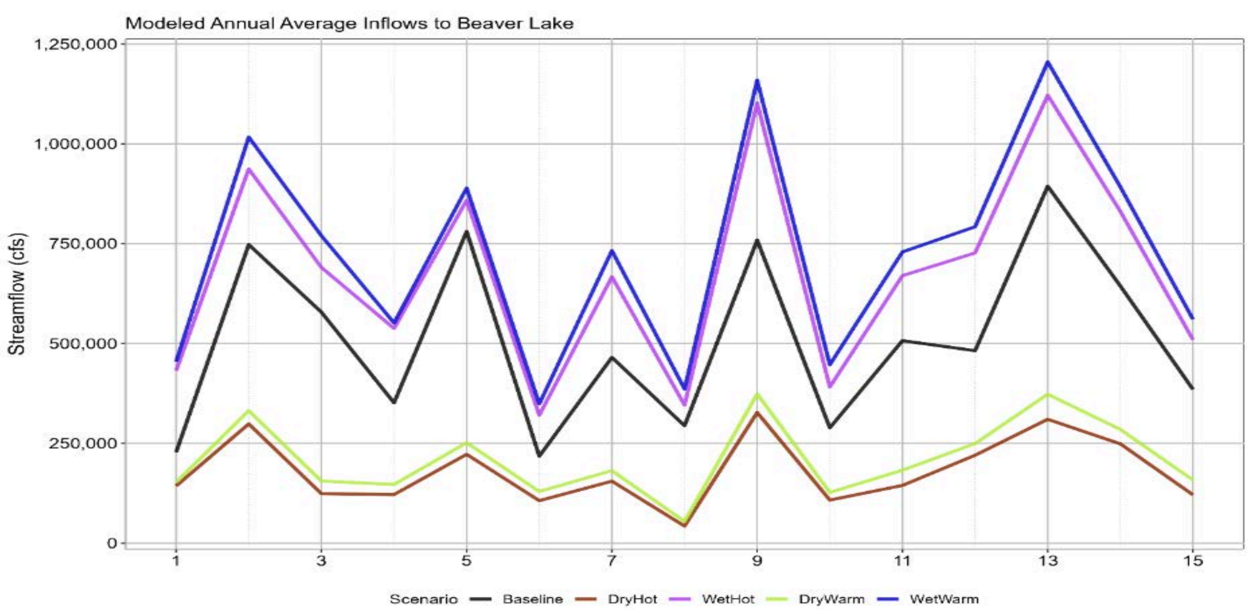


Figure 2-31. Model Annual Inflow into Beaver Lake for Baseline and Future Climate Scenarios, including DryHot, WetHot, DryWarm, and WetWarm Defined within the Text (15-year period).

Within these future scenarios, the changes to peak, average, and low flows across the subwatersheds are visualized through flow duration curves in Figure 2-32. White River and War Eagle Creek follow the same general trends as in the Baseline scenario, with White River exhibiting a slightly flashier regime with higher peak flows and lower baseflows. However, in the Dry Hot and Dry Warm scenarios, the baseflows in White River are significantly lower than the baseflows in War Eagle Creek. In these two scenarios, White River, Brush Creek, and Richland Creek all have low flows that are simulated as less than 0.1 cubic feet per second (cfs). In the Wet Hot and Wet Warm scenarios, all four subwatersheds follow similar trends as the Baseline scenario, although the low flows at Richland Creek are higher, but still under 0.1 cfs.

The annual average sediment, nitrogen, and phosphorus loads for each of four future climate scenarios by subwatershed are shown in Figure 2-33. War Eagle Creek has the highest average annual loads for all three parameters. The range in average annual loads is also largest in War Eagle Creek across all four scenarios except the range of nitrogen loads is larger at White River for the Wet Hot and Wet Warm scenario.

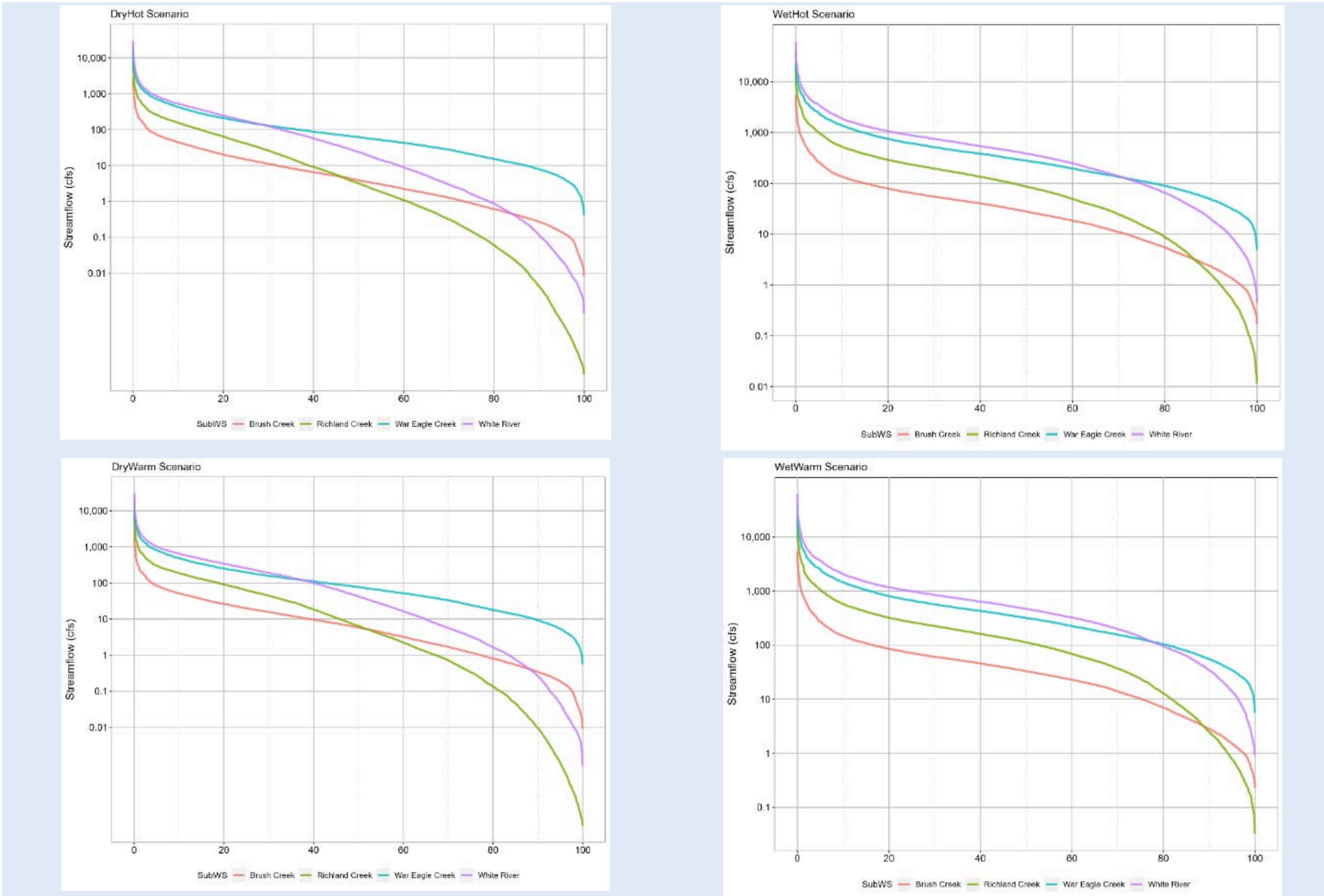


Figure 2-32. Model Flow Duration Curves for Each Future Climate Scenario by Subwatershed in the Beaver Lake Watershed.

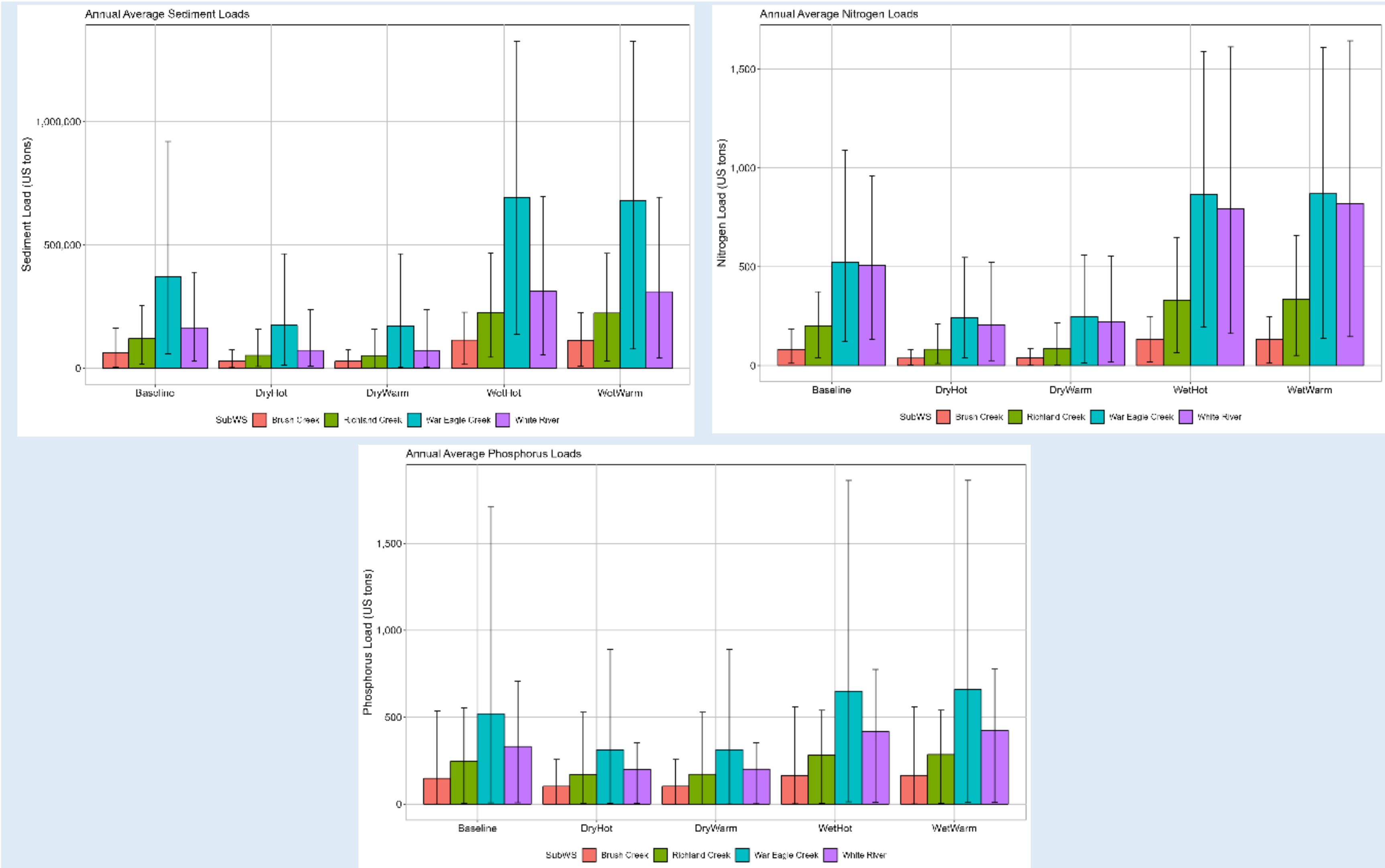


Figure 2-33. Model Annual Average (Mean ± Standard Deviation) Loads to Beaver Lake by Climate Scenario and Subwatershed. Graphs are for Sediment (Top Left), Nitrogen (Top Right), and Phosphorus (Bottom).

The modeled flows and sediment and nutrient loads from the Future Land Use scenario alone and in combination with the two more extreme climate scenarios (Wet Warm and Dry Hot) are shown in Table 2-6.

The Future Land Use scenario shows little difference from the baseline scenario, which is expected as there are only slight changes to certain portions of the watershed expected. Including the climate scenarios with the land use change brings about more change from the land use scenario but does not produce much more change than climate alone (as compared to Table 2-5). While the Future Land Use with Dry Hot climate scenario shows large decreases in loads due to decrease in flows, the concentrations of nutrient are predicted to increase within the rivers at the point of inflow to Beaver Lake.

The streamflows by subwatershed exhibited very little change from the Baseline distribution in streamflows for the land use change alone scenario. There are some changes with increases in the high and low flows, although less change in the middle flows, in the Future Land Use with Wet Warm climate. Across the subwatersheds, the relative contributions of sediment and nutrient loads from each subwatershed remained consistent across the scenarios (Figure 2-34). For sediment and phosphorus, War Eagle Creek contributes the largest loads, but for nitrogen, White River contributes a similar amount to War Eagle Creek. Sediment loads and ranges by land use scenarios are presented in Table 2-7 for better comparison across subwatersheds and scenarios.

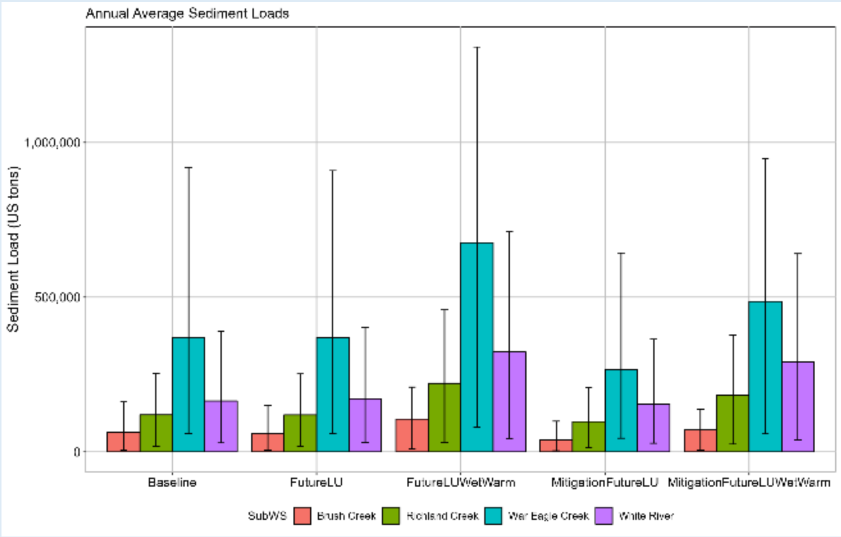
Table 2-6. Modeled Flows and Average (Mean) Annual Sediment, Nitrogen and Phosphorus Loads and Concentrations from the Major Tributaries to Beaver Lake with Directional Change (i.e., Increases ↑ or Decreases ↓) for the Future Land Use-Based Scenarios[1]

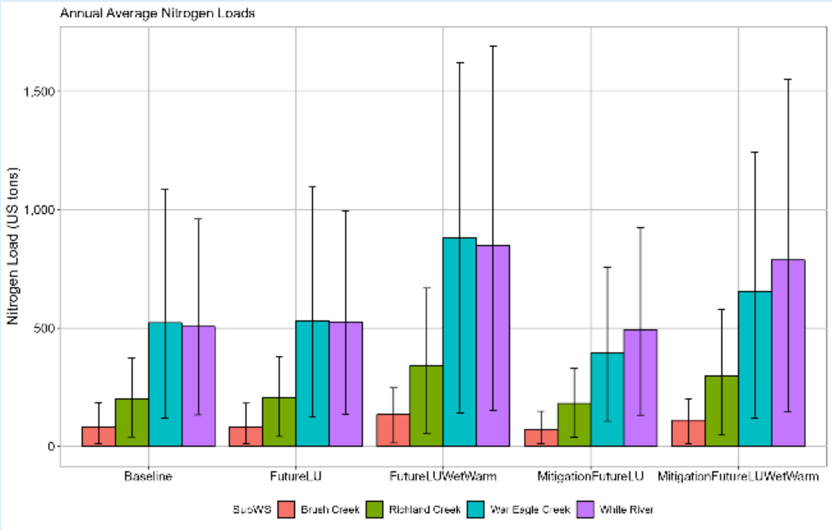
Scenario	Mean Annual Flow (cfs)	Average Daily Flow (cfs)	Sediment Load (US tons)	Nitrogen Load (US tons)	Phosphorus Load (US tons)	Sediment Concentration (mg/L)	Nitrogen Concentration (mg/L)	Phosphorus Concentration (mg/L)
Baseline	486,730	360	651,410	1,191	1,130	231	1.51	0.70
FutureLU	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
FutureLUWetWarm	Increase ↑	Increase ↑	Increase ↑	Increase ↑	Increase ↑	Increase ↑	Decrease ↓	No change
FutureLUDryHot	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓	Decrease ↓	Increase ↑	Increase ↑	Increase ↑

[1]These total loads do not include the direct drainage for Beaver Lake nor that from Brush Creek, and modeling results for FutureLU scenario were within 5% or less of the baseline model results so no directional change was reported, as well as with phosphorus concentration for FutureLUWet..

Table 2-7. Modeled Average (Mean) Annual Sediment Loads (US tons) with Range (Minimum and Maximum) to Beaver Lake by Future Land Use-Based Scenarios

Inflow Subwatershed	Statistic	Baseline (US tons)	FutureLU (US tons)	FutureLU/WetWarm (US tons)	FutureLU/DryHot (US tons)
White River	Mean Range	164,650 (28,940 – 389,860)	172,180 (31,260 – 403,410)	322,750 (44,120 – 711,080)	77,140 (9,850 – 246,930)
Richland Creek	Mean Range	119,810 (17,340 – 253,300)	119,500 (17,770 – 252,010)	222,030 (29,980 – 459,040)	52,660 (7,050 – 156,970)
Brush Creek	Mean Range	62,970 (5,680 – 161,440)	59,780 (5,710 – 150,510)	106,370 (9,270 – 209,750)	27,360 (2,750 – 69,420)
War Eagle Creek	Mean Range	370,420 (58,690 – 920,180)	369,140 (59,610 – 908,990)	613,902 (71,455 – 1,188,013)	174,390 (12,480 – 461,090)





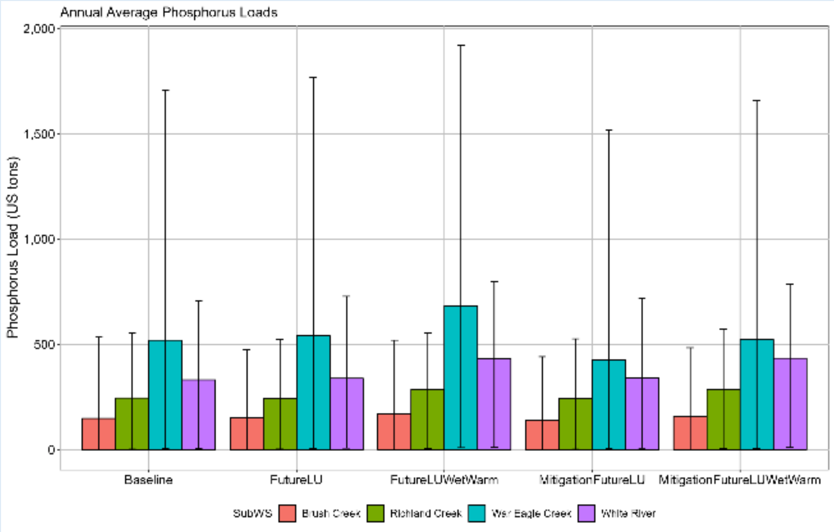


Figure 2-34. Model Annual Average (Mean ± Standard Deviation) Loads to Beaver Lake by Future Land Use and Mitigation Scenario and Subwatershed. Graphs Are for Sediment (top left), Nitrogen (top right), and Phosphorus (bottom).

These comparisons have focused on the mean annual averages and totals. However, peak loads drive these annual averages. Comparing the identified major storms within the period of record shows that the peak sediment and nutrient loads during these events do not greatly increase across the future scenarios except for the December 2015 storm that experienced widespread rainfall throughout watershed. The lack of change in these peak events suggests that as currently simulated, these events are washing off all ***available*** surficial sediments (i.e., maximizing transport capacity and erodible surficial soils) over the course of the storm and transporting the loads to the lake. Therefore, the increases of loadings during the future wet climate scenarios are driven by higher loadings during mid-range storm events.

To examine the potential future changes to water quality spatially across the watershed, the locally generated loads from the scenario including future land use change and a wetter and warmer climate are presented in Figure 2-35 through Figure 2-37. The biggest increases in generated land-derived loadings of sediment are predicted in the lower reaches of the three forks of the White River and around the western side of the lake, although the overall trends throughout the watershed are for large increases in the locally generated land-derived loads. The phosphorus loads originating in the West Fork White River are predicted to have the greatest increase under the future scenario. Overall, the greatest increases from baseline conditions are seen with nitrogen where loads are doubling throughout most of the watershed and more than doubling at the downstream ends of the White River forks and Brush Creek, like sediment.

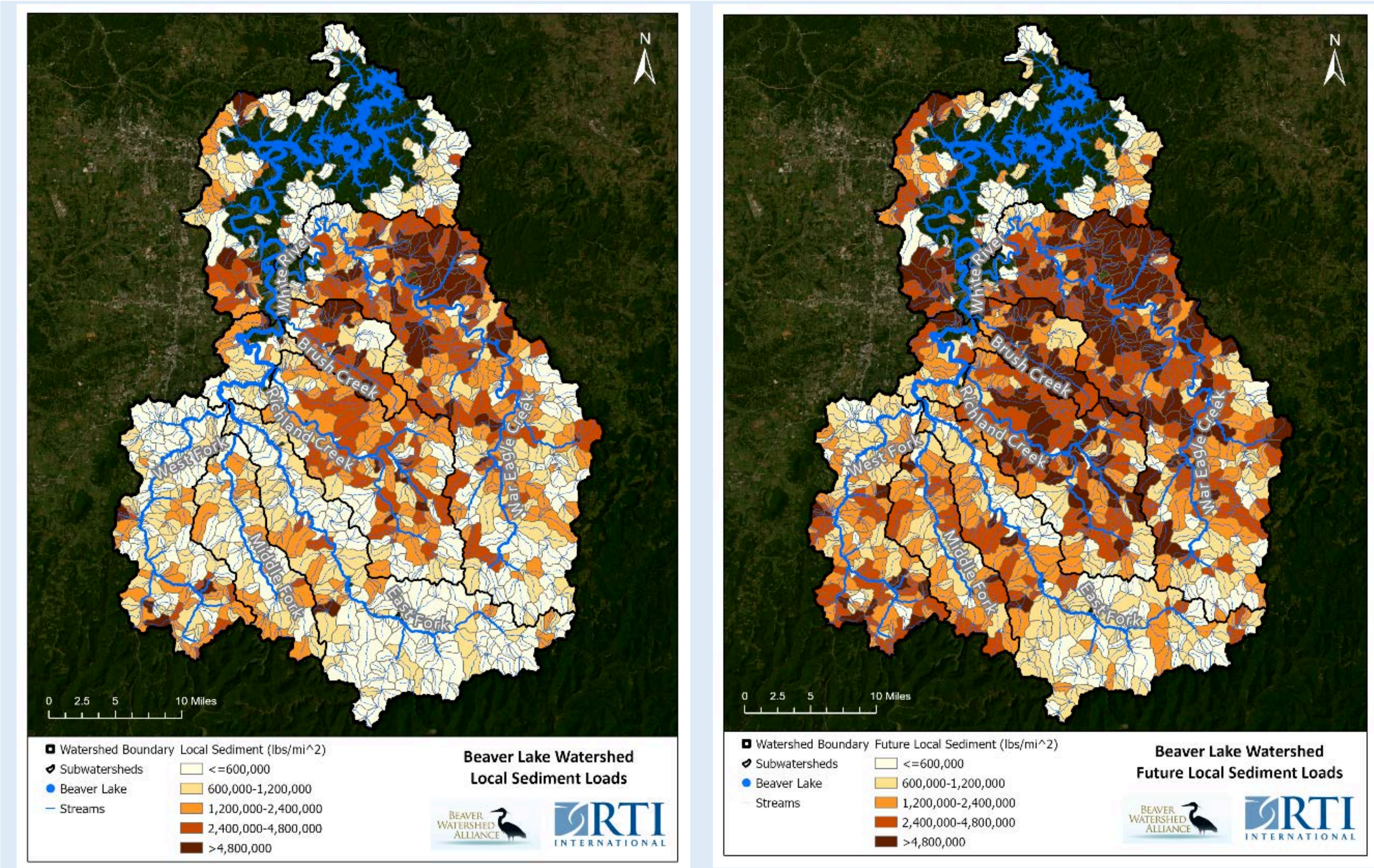


Figure 2-35. Comparison of Model Baseline and Future Sediment Loading from NLDPlus Catchments across Beaver Lake Watershed.

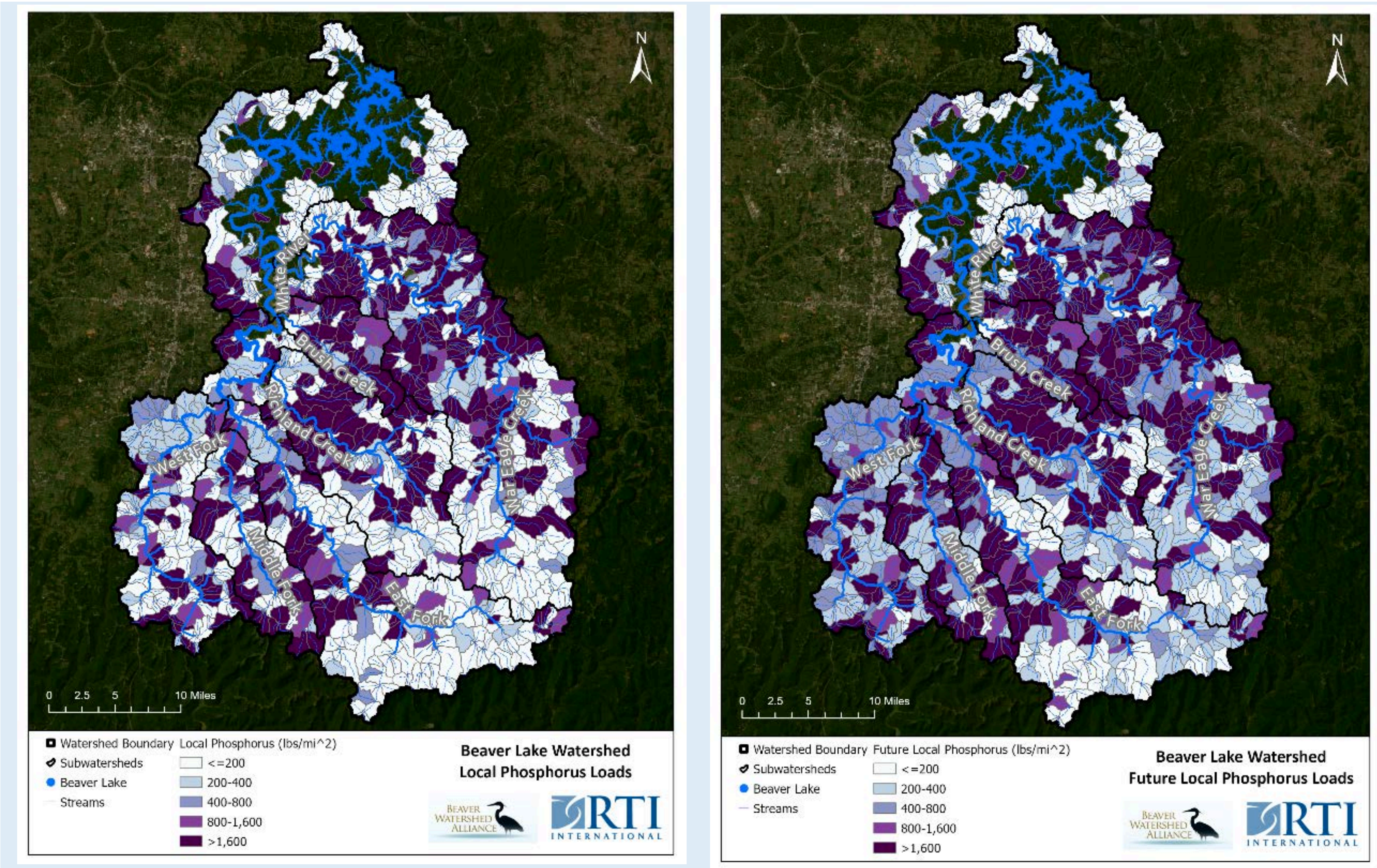


Figure 2-36. Comparison of Model Baseline and Future Phosphorus Loading from NLDPlus Catchments across Beaver Lake Watershed.

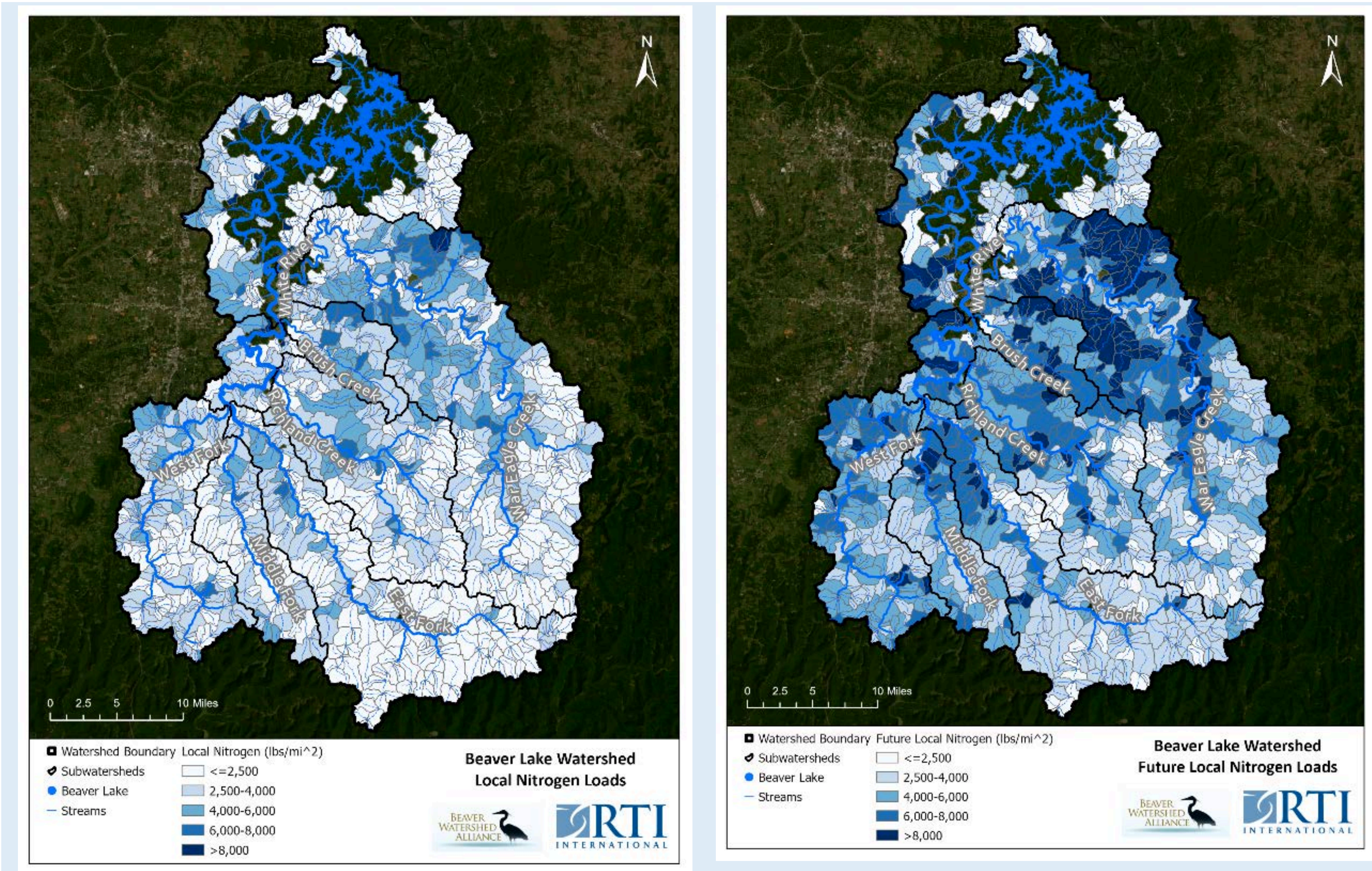


Figure 2-37. Comparison of Model Baseline and Future Nitrogen Loading from NLDPlus Catchments across Beaver Lake Watershed.

2.2.5 River Instability and Resulting Streambank Erosion

This section was contributed by Sandi Formica and Matthew Van Eps from the Watershed Conservation Resource Center

River instability and resulting streambank erosion are a potential major source of sediment and nutrients to impaired waterways in the Beaver Lake watershed. This source of sediment and nutrients is being presented separate from the watershed-based model analysis, since modeling streambank erosion is difficult, if not impossible, to perform with a meaningful level of accuracy. Streambank erosion is an important piece of watershed sediment and nutrient budgets and puzzle, as well as upland erosion and floodplain deposition.

Accelerated streambank erosion and channel instability present challenges for water resource managers for a variety of reasons:

- Accelerated streambank erosion releases thousands of tons of sediments and thousands of pounds of nutrients into the waterways, annually, impacting water quality.
- As streambanks retreat (Figure 2-38), valuable lands including forested riparian and pasture are lost, impacting agricultural producers and other landowners; the associated loss of vegetation root mass exposes banks to further accelerated erosion and exacerbates land loss.
- Critical infrastructure including roadways and utilities may be threatened or damaged.
- Unstable river systems do not support healthy aquatic habitat resulting from the loss of mature, shading trees, higher water temperatures, siltation and smothering of gravel substrates, and lack of high-quality fish habitat.
- Unstable river systems compromise healthy riparian areas impacting riverine wetlands and floodplains that slow flood waters, filter pollutants, support wildlife, and provide ecosystem resiliency.
- The loss of large numbers of trees can result in river debris jams that generate additional river instability and impacts to recreational activities including impediments and safety hazards for primary and secondary recreational activities.
- Native soils are a sink for nutrients including nitrogen and phosphorus, and when these soils are eroded, the resulting displaced sediment can contribute significant nutrient loading downstream.

Figure 2-38. Cutbanks on the Middle Fork White River
Erosion, Such as this Contributes Thousands of Tons of Sediment Annually (Photo from 2022).

Causes of channel instability are directly related to watershed land use changes and ecosystem impacts occurring since the late 1800s. River systems respond to watershed hydrology, sediment loading, and the health of riparian vegetation. The building of roads and clearing of the forest in the Beaver Lake watershed dates to the late 1800s, while the trapping and removal of beaver pre-dates that era. Initially trees were harvested to construct railroads. The resulting logging roads allowed for continued and easy access to further harvest timber from the Ozark forests, increasing stormwater runoff and sediment loads to the network of streams and rivers in the Beaver Lake Watershed. More recently, land use changes that impact channel stability include converting forested lands to pasture, channel alteration to create additional pasture or build infrastructure, improperly designed low water crossings and bridges, removal of riparian vegetation, such as trees and river cane, filling of riverine wetlands, in-stream gravel mining, and urban development resulting in a dramatic increase in impervious surfaces. These land use changes impact the stability of rivers accelerating streambank erosion and sediment yield throughout the watershed. Finally, the induced river instability and impaired riparian buffers in the Beaver Lake Watershed impact the resiliency of its waterways to adapt to climate change.

In-Channel Erosion Monitoring and Assessment

As described above, river or stream channel instability has the potential to generate a substantial load of sediment and nutrients from the watershed. Further, it has been shown that in watersheds with anthropogenic impacts and induced instability, channel-source sediments from bed/bank erosion and gullying can far exceed the sediment yield from upland sources such as hillslopes and unpaved roads. Streambanks with upslope grass are more likely to erode than those with forested banks in regional watersheds (Harmel, Haan, and Dutnell, 1999a). Understanding the relative magnitude of this source of loading is paramount to evaluating the value of on-the-ground efforts and funding allocated to activities that are intended to protect or improve water quality in the watershed. For example, a watershed-based assessment of sediment loadings to the West Fork White River (WFWR) performed by ADEQ in 2004 suggests that in-channel processes that result in streambank erosion can generate sediment loads that are significantly larger than other sources in the watershed. The investigation suggested that 66% of the annual sediment load (which included unpaved roads, pastures, forest, construction areas, and urban areas) was from accelerated streambank erosion (Arkansas Department of Environmental Quality, 2004). The degree to which sediment loading is dominated by channel-source sediments within the WFWR likely suggests that a similar or greater magnitude of relative loading dominance occurs in other subbasins within the Beaver Lake watershed. This necessitates that this principal source of sediment and nutrients be considered during the watershed planning process for Beaver Lake watershed in general, but particularly where turbidity, total suspended solids, sediment, and/or nutrients are the pollutants of concern in impaired or threatened waterbodies.

Beginning in 2005, a variety of streambank erosion monitoring efforts have been conducted by the WCRC working with local partners, landowners, government agencies, and nongovernmental organizations to evaluate erosion processes and to develop loading estimates throughout the Beaver Lake watershed. Streambank erosion monitoring was often associated with proposed restoration activities, as well as for sites showing signs of accelerated erosion. The WCRC has found that utilizing GIS analysis of historical aerial photography, field data collected over time, the development of streambank erosion prediction curves, and streambank soil sampling and nutrient analysis provides the information needed to calculate sediment and nutrient loadings from streambank erosion (Van Eps, Formica, Morris, Beck, & Cotter, 2004; USDA NRCS and WCRC , 2021). However, streambank stability ratings are not always a good predictor of the potential for sediment and nutrient loading in regional watersheds (Harmel, Hann, and Dutnell, 1999b). Figure 2-39 shows an example of streambank erosion monitoring utilizing GIS as well as field measurement techniques. This information has and can be used to help determine priority sites for restoration (Formica and Van Eps, 2010; USDA NRCS and WCRC, 2020). The monitoring performed over the last two decades shows that sediment and nutrient loading from in-channel processes regularly exceed several thousand tons of sediment per year for an unstable reach of river, on an average basis over time. A ton of native soil may contain over one pound of phosphorus, as a result this sediment also conveys with it phosphorus loads of several thousand pounds per year.

Characterizing streambank soils is an integral part of streambank monitoring. It provides important data needed to calculate sediment loadings. Analysis of soil samples collected from streambanks provides total phosphorus and total nitrogen concentrations, so that phosphorus and nitrogen loadings can be determined. Methods for sampling streambanks are described in Brye et al. (2004).

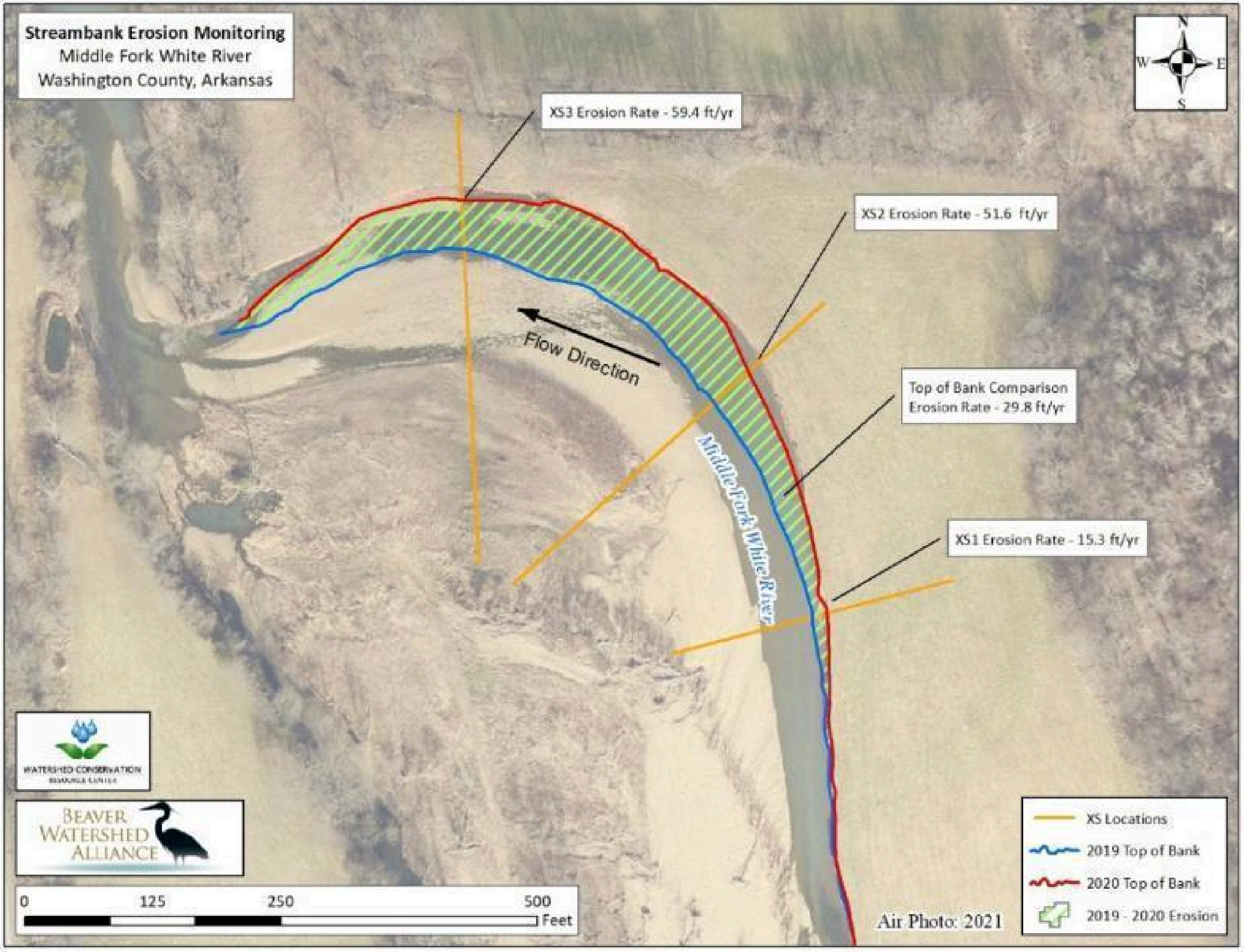


Figure 2-39. Example of Streambank Erosion Monitoring along a Bank on the Middle Fork of the White River.

Also, understanding the particle size of sediment entering the waterway and characterizing it based on particles greater than 2 mm (bedload) and particles equal to or less than 2 mm (suspended load of sediment) provides data needed to evaluate water quality and stream stability impacts resulting from in-channel erosion processes. Table 2-8 is a summary of streambank sampling results of sites in the WFWR watershed used to calculate sediment and nutrient loadings from streambanks. The data presented are representative of fine (no gravels) and coarse (very gravelly) streambank materials as observed in the WFWR watershed. To estimate sediment and nutrient loading from a particular streambank of interest, the relative composition of the streambank, based on observed strata must be known. Once known, the average bulk densities, total phosphorus, and total nitrogen concentrations from this table could be used on a prorated basis depending on the percentage of bank composed of fine and coarse materials to determine the sediment and nutrient load that would result for a given volume of eroded streambank material.

Table 2-8. Streambank Sampling Results for Sites in the West Fork of the White River (Provided by Watershed Conservation Resource Center, 2023)

Sample Site	*Fine Samples*			*Coarse Samples*		
	Bulk Density lb/ft^3	T. Phosphorus lb/ton	Total Nitrogen lb/ton	Bulk Density lb/ft^3	Total Phosphorus lb/ton	Total Nitrogen lb/ton
WFWR at Dye Creek	83.49	0.18	1.41	116.84	0.22	0.22
WFWR Airport	92.03	0.52	1.71	103.61	0.29	0.50
WFWR Brentwood Mountain	90.29	0.77	1.13	177.95	0.35	0.41
WFWR Pump Station	82.75	0.53	0.63	*n/a*	*n/a*	*n/a*
Ground Cherry Creek	79.61	0.60	1.34	106.42	0.24	0.27
Average	**85.63**	**0.52**	**1.24**	**126.20**	**0.28**	**0.35**

Using aerial photography and field data, average sediment loadings from streambanks showing signs of accelerated erosion in the WFWR watershed were evaluated from 2004 through 2016. The total sediment load to the WFWR watershed from these sites averaged 139,000 tons per year. This value includes both bedload and suspended load and includes several record and near record flood events. Approximately, 65% of the total sediment load is the suspended load (Van Eps, Formica, Morris, Beck, & Cotter, 2004), which is 90,000 tons per year from the watershed. Most of this material is transported during storm runoff events and would enter the White River, though when waters begin to recede, some would settle onto floodplains, point bars, and wetlands, as well as within the stream channel. This loading value represents the numeric average over the 12-year period between 2004 and 2016. Using the average values presented in Table 2-8, the average phosphorus load over this period would be 60,520 pounds per year. This could account for more than 60% of the total phosphorus load within the WFWR watershed, based on WFWR load estimates from the Arkansas Water Resources Center (AWRC; Grantz and Haggard, 2023).

Streambank erosion monitoring following implementation of stream restoration projects allows for the effectiveness of this best management practice to be evaluated. Reduction of sediment and phosphorus loadings because of stream restoration projects in the Beaver Lake watershed are generally greater than 95% for a given project reach. However, understanding the bioavailability of this phosphorus source is critical to watershed management, and phosphorus bioavailability in soils and sediments is an elusive parameter to measure. The best estimates are that bioavailable phosphorus accounts for 12% of total streambank phosphorus on average and is usually less than 25% (Lammers and Bledsoe, 2017).

2.3 Water Quality Standards

This section provides an overview of the current state water quality standards (WQS) applicable to the Beaver Lake Watershed. Some site-specific benchmarks developed as a part of the Strategy are also included, where a benchmark is a non-regulatory objective. Both standards and benchmarks are quantitative – they can be measured. The benchmarks are proposed when there are no regulatory standards, but certain conditions are desired in the lake, or as a safety factor for a regulatory standard’s minimum threshold. The EPA recommends using 80% of a criterion as a safety factor to increase likelihood of staying below the criterion. The benchmark also addresses variability between the modeling and monitoring. The benchmark, however, is not assigned to the ambient WQS, as the standards themselves are more forgiving in that they are measured by a statistic such as geometric mean or annual mean.

In the 2012 strategy, two locations were proposed for meeting the WQS (referred to as targets in the 2012 strategy) and benchmarks: the Hickory Creek monitoring station as well as USGS monitoring station 07049200 Beaver Lake near Lowell (L3), which is close to the District’s raw water intake. For this Strategy update, the Alliance chose to add an additional USGS station, 07049500 located at the Highway 12 Bridge near Rogers, to provide a larger picture of water quality in the lake. The Hickory Creek station was selected as an early warning indicator for the rest of the lake, as it is at the confluence of the major tributaries to Beaver Lake and the lake’s “plunge point,” where incoming water from the White River moves below the existing pool of impounded water in the lake. It is also upstream of the District’s intake. This station was managed by the USGS until 2018 and is now managed by the District and the Arkansas Water Resource Center (AWRC). Also, if the Strategy is protective of conditions in the lake at Hickory Creek, it is expected to be protective of the rest of the lake. All three of the monitoring locations are shown in Figure 2-40.

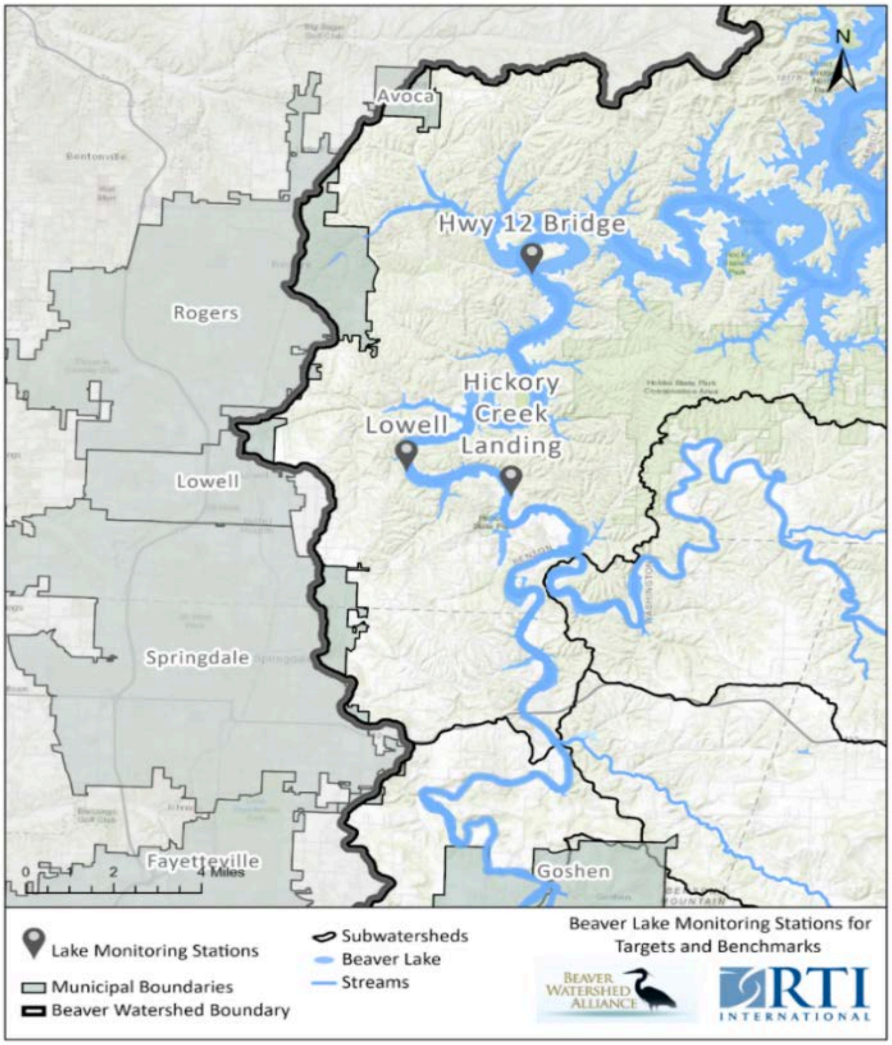


Figure 2-40. Lake Monitoring Stations for Targets and Benchmarks at Beaver Lake.

Each of these stations have specified WQS approved for the Clean Water Act. The Arkansas DEQ has developed proposed WQS for the entire state, which are approved and adopted by the Arkansas Pollution Control and Ecology Commission (APC&EC). Within the APC&EC Rule No. 2, revised 2020 (Arkansas Pollution Control and Ecology Commission, 2020), WQS have been defined for each ecoregion within the state, with some additional site-specific standards included for the Hickory Creek Station of Beaver Lake. Table 2-9 summarizes standards that apply to the Ozark Highland ecoregions, which includes Beaver Lake, and the Hickory Creek Station, which is located on Beaver Lake. In terms of water quality, there only exists an ecoregion-level standard for turbidity. There does not exist a statewide standard for chlorophyll *a* nor total organic carbon (TOC). However, in the 2012 strategy, site-specific standards were developed for the Hickory Creek Station for chlorophyll *a*, water clarity (Secchi depth), and TOC. These standards are only applicable at the Hickory Creek Station of Beaver Lake.

Table 2-9. Summary of Statewide and Site-Specific Criteria for Water Quality for Beaver Lake.

Parameter	Designated Use	Criteria	Origination	Location Applicability
Turbidity	Domestic Water Supply, Aquatic Life	◆ 10 NTU ◆ 17 NTU	APC&EC Rule No. 2	Ozark Highlands ecoregion
Chlorophyll *a*	Domestic Water Supply	8 µg/L	Developed in 2012 Strategy; Adopted by APC&EC Rule No. 2	Beaver Lake: Hickory Creek Station
Water Clarity (Secchi depth)	Domestic Water Supply	1.1 m	Developed in 2012 Strategy; Adopted by APC&EC Rule No. 2	Beaver Lake: Hickory Creek Station
Total Organic Carbon (TOC)*	NA	3 mg/L*	Developed in 2012 Strategy	Beaver Lake: Hickory Creek Station

**Not applicable to Rule 2*

2.3.1 Site-Specific Criteria for the Hickory Creek Station

The site-specific standards or targets included in Table 2-9 are for measurement at the Hickory Creek Station for three key indicators: chlorophyll *a*, TOC, and water clarity. These water quality standards have not changed since the 2012 Strategy. Furthermore, as the standard was developed only for use at Hickory Creek (e.g., see Scott and Haggard, 2015), these standards should not be applied to the other monitoring locations, but the data are included to understand how water quality changes throughout the lake.

The TOC target of 3 mg/L is not part of the statewide standards, but was developed as part of the 2012 Strategy, and is based on the Safe Drinking Water Act *Disinfection By-products Rule*. This target ensures that the intake near Lowell station is below the level where the formation of trihalomethane (TTHM), a disinfection byproduct that can occur when reacting with chlorine used in the drinking water treatment process, occurs.

The chlorophyll *a* and water clarity criteria (collectively standards) are adopted by the APC&EC Rule No.2. (Arkansas Pollution Control and Ecology Commission, 2020). The chlorophyll *a* standard for Hickory Creek is set at 8 µg/L, measured as the seasonal geometric mean. The water clarity criterion for Hickory Creek is set at 1.1 meters Secchi depth, measured as the annual average (mean). The standard is established by the APC&EC regulations and is based on DEQ water quality criteria for turbidity in streams, as well as TMDLs for the West Fork and Lower White River. The targets are to meet instream turbidity criteria to address stream and lake turbidity. However, it is important to note that this location should be considered a lake sample according to DEQ's AquaView. In addition, DEQ TMDLs require a 53 – 58% (depending on flow category) reduction of the sediment load in the West Fork of the White River and a 32 – 40% reduction in the Lower White River subwatersheds.

Each indicator's annual averages (except for chlorophyll *a*, where the seasonal geometric mean is taken) for each of the monitoring locations are summarized below, and the exceedance of the target or benchmark is evaluated. The data were compiled from the USGS NWISWeb Database for the following parameters: p00078: Transparency, Secchi disc; p00680: Organic carbon; and p70953: Chlorophyll *a.* Hickory Creek chlorophyll *a* field data and Chl *a*-pheo corr-fluorometric lab data for 5/22/2019 through 12/13/2021 were provided by the Beaver Water District for the BWD/AWRC HC Station: Beaver Lake near Hickory Creek.

The initial set of data for USGS Station 07049200 is taken from the 2012 Strategy, while years 2009 to 2021 were updated as of January 2022. As USGS Station 07049500 is a new station added to the Strategy, all data from 2001 through 2021 are calculated for this Strategy. Data for the Hickory Creek Station is missing for 2001 to 2007, as public data are not available for that period. The data being evaluated are provided in Table 2-10 through Table 2-12.

2.3.2 Chlorophyll *a* Criterion

The recommended chlorophyll *a* WQS for Hickory Creek is 8 μg/L meaning the benchmark, 80% of the WQS, is 6.4 μg/L. Between 2008 and 2021 at Hickory Creek Station, the values ranged from 6.2 to 12.3 μg/L. The values in 2009 – 2014 and 2017 – 2021 exceeded the WQS. Only 2015 remained under the benchmark for chlorophyll *a*. These values, as represented in Table 2-10 and Figure 2-41, emphasize the importance of developing and implementing a strategy to achieve no or relatively little increase in total phosphorus and total nitrogen loading to the lake. Figure 2-42 compares the chlorophyll *a* values at select monitoring locations within Beaver Lake; however, the criterion is not included as it only applies to the Hickory Creek Station.

Table 2-10. Chlorophyll a Seasonal Geometric Mean (µg/L) for Select Monitoring Locations at Beaver Lake from 2001 through 2021. Values in red exceed the DEQ Standard

Monitoring Year	USGS Station (07049187) and Beaver Water District/AWRC Station at Hickory Creek	USGS Station (07049200) at Lowell (L3)	USGS Station (07049500) at the Highway 12 Bridge near Rogers
DEQ STANDARD	**8**	**N/A**	**N/A**
2001	-	6.1	2.9
2002	-	4.5	4.5
2003	-	4.9	3.2
2004	-	5.3	4.1
2005	-	3.7	2.7
2006	-	4.2	3.0
2007	-	5.9	2.9
2008	-	7.9	5.5
2009	**9.6**	9.5	5.6
2010	**12.3**	8.3	3.9
2011	**8.0**	7.5	5.0
2012	**11.2**	8.8	3.8
2013	**9.3**	7.3	5.1
2014	**8.0**	6.4	3.1
2015	6.2	6.3	5.3
2016	7.9	6.4	3.4
2017	**8.4**	6.9	6.2
2018	**8.7**	6.7	6.0
2019	**12.3**	7.3	4.8
2020	**11.9**	9.0	5.5
2021	**8.2**	9.9	6.0

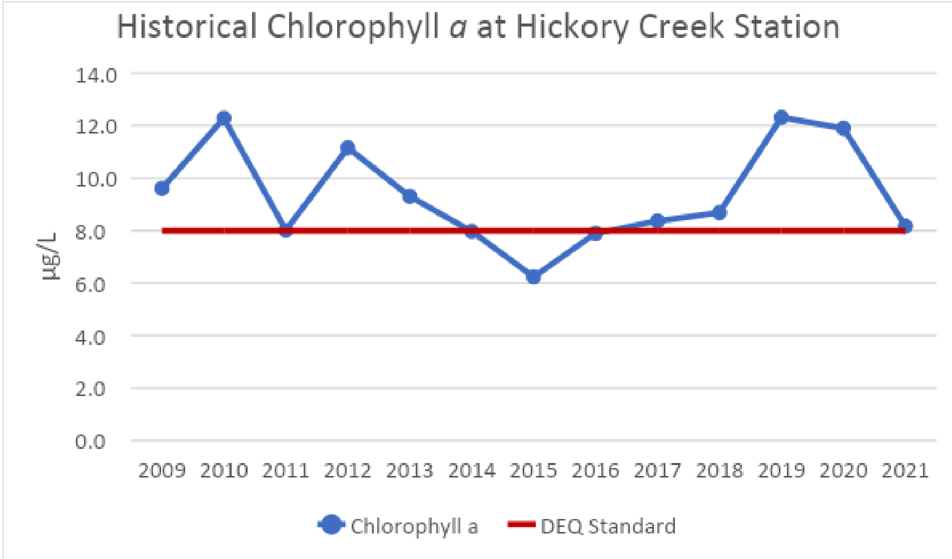


Figure 2-41. Historical Chlorophyll a Seasonal Geometric Mean (µg/L) at Hickory Creek Station on Beaver Lake from 2009 through 2021.

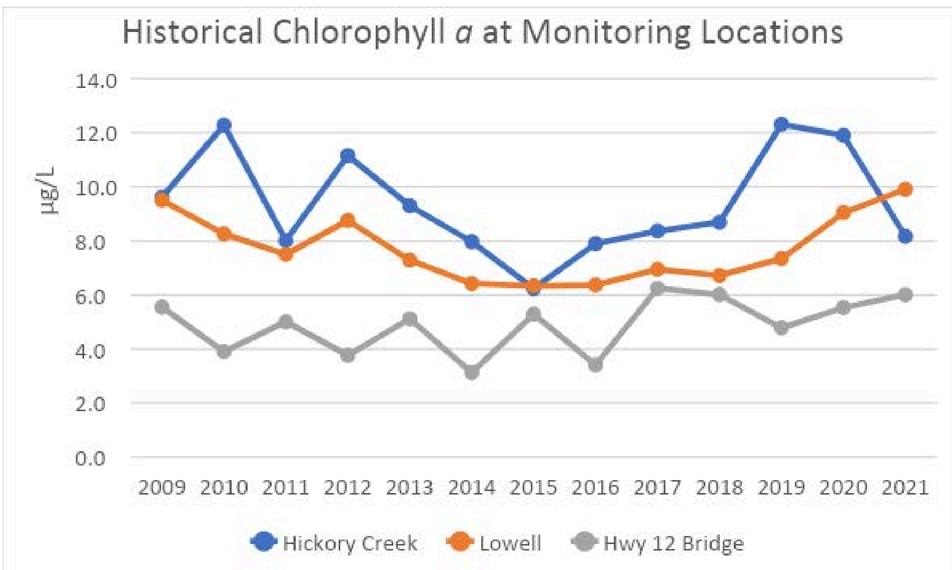


Figure 2-42. Historical Chlorophyll a Seasonal Geometric Mean (µg/L) at Select Monitoring Locations on Beaver Lake from 2009 through 2021.

2.3.3 Total Organic Carbon Benchmark

The recommended TOC target is 3 mg/L at the Hickory Creek Station. As noted earlier, this is not a criterion under the APC&EC Rule No. 2; rather a water quality translator to protect the drinking water quality and reduce the risk of disinfection byproducts during drinking water treatment processes. At the Hickory Creek Station, the values ranged from 2.6 to 3.8 mg/L between 2008 and 2021 and the target was exceeded in 2008, 2009, 2011, and 2013, as represented in Table 2-11 and Figure 2-43. Meeting the standard on a consistent basis would mean developing a strategy to achieve relatively little or no increase in TOC loading to the lake or production within the lake. Figure 2-44 compares the TOC values at select monitoring locations within Beaver Lake; however, the benchmark is not included as it only applies to the Hickory Creek Station upstream from the District.

Table 2-11. Average (Mean) Total Organic Carbon (TOC) Concentrations (mg/L) for Select Monitoring Locations at Beaver Lake.
Values in red exceed the target.

Monitoring Year	USGS Station (07049187) and Beaver Water District/AWRC Station at Hickory Creek	USGS Station (07049200) at Lowell (L3)	USGS Station (07049500) at the Highway 12 Bridge near Rogers
STANDARD	***3***	***N/A***	***N/A***
2001	-	2.3	2.5
2002	-	3.2	2.9
2003	-	2.2	2.3
2004	-	5.0	4.0
2005	-	2.7	2.8
2006	-	3.6	2.8
2007	-	3.0	2.8
2008	**3.3**	3.9	3.4
2009	**3.8**	3.4	3.1
2010	2.8	2.7	2.3
2011	**3.3**	3.6	3.5
2012	2.6	2.6	2.4
2013	**3.3**	3.1	2.7
2014	2.8	2.8	2.5
2015	3.0	2.8	2.3
2016	2.9	2.8	2.8
2017	2.9	3.8	3.5
2018	2.7	3.4	2.9
2019	1.8	3.1	2.7
2020	1.8	2.8	2.5
2021	1.4	2.8	2.5

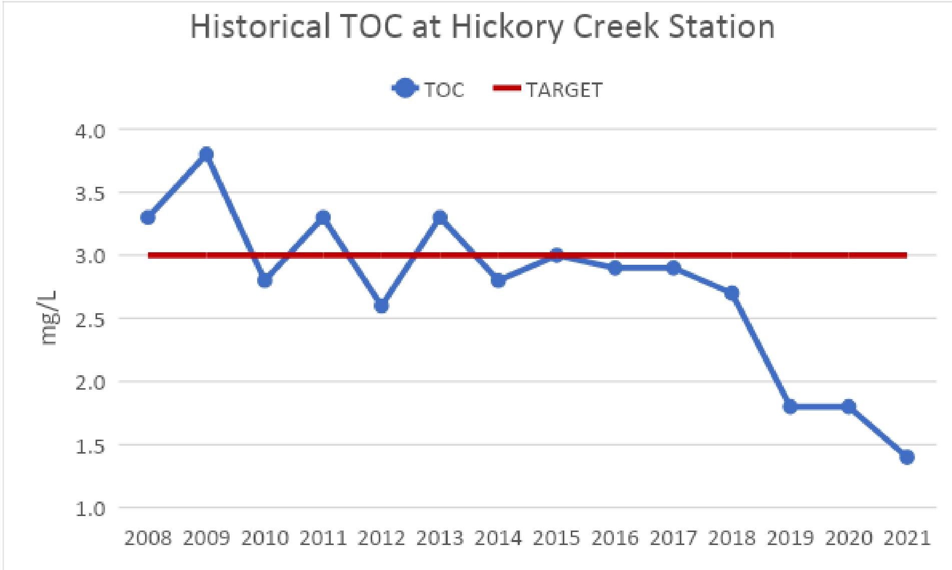


Figure 2-43. Historical Average (Mean) Total Organic Carbon (TOC) Concentrations at the Hickory Creek Station on Beaver Lake from 2008 through 2021, Showing the TOC Target of 3 mg/L.

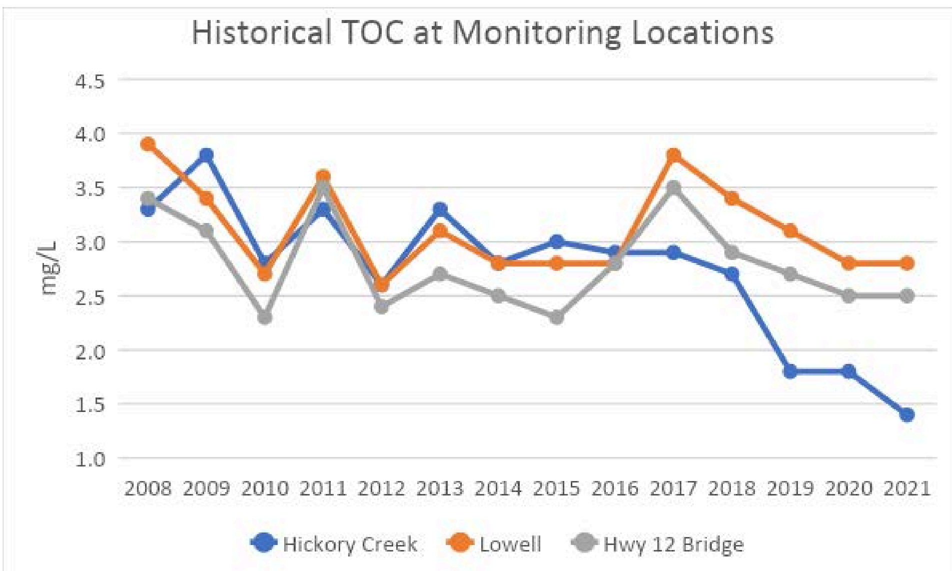


Figure 2-44. Historical Average (Mean) Total Organic Carbon (TOC) Concentrations at Select Monitoring Locations on Beaver Lake from 2008 through 2021.

2.3.4 Water Clarity Criterion

The recommended water clarity criterion and benchmark in Beaver Lake is an average (mean) annual Secchi depth (water clarity) of 1.1 m at Hickory Creek. Measuring Secchi depth not only includes suspended sediment, but also algae within depth measured via the Sechi disc. The target is that Secchi depth should be greater than 1.1 m, as Secchi depths of 1.1 m or less would violate the WQS for this site at Beaver Lake. At Hickory Creek, various years including 2009, 2010, 2011, 2012, 2015, 2016, and 2019 had Secchi depths less than 1.1 m, as shown in Table 2-12 and Figure 2-45. The high level of violations for this indicator point to a need for protection measures that decrease or maintain existing levels of sediment/turbidity loading to the lake, as well as reducing algal growth and nutrient inputs to the lake. Figure 2-46 compares the Secchi depth values at select monitoring locations across Beaver Lake; however, the criterion is not included as it only applies to the Hickory Creek Station upstream from the District.

Table 2-12. Secchi Depth Annual Average (Mean) in Meters for Select Monitoring Locations on Beaver Lake. Values in red violate the criterion

Monitoring Year	USGS Station (07049187) and Beaver Water District/AWRC Station at Hickory Creek	USGS Station (07049200) at Lowell (L3)	USGS Station (07049500) at the Highway 12 Bridge near Rogers
DEQ STANDARD	**1.1**	N/A	N/A
2001	-	2.3	2.7
2002	-	2.0	2.4
2003	-	2.2	2.3
2004	-	1.3	1.7
2005	-	2.4	2.0
2006	-	2.2	2.2
2007	-	2.0	2.7
2008	**1.3**	1.1	1.6
2009	**1.0**	1.2	1.7
2010	**1.1**	1.4	2.2
2011	**1.0**	1.0	1.4
2012	**1.0**	1.1	1.9
2013	**1.2**	1.4	2.1
2014	**1.2**	1.5	2.0
2015	**1.1**	1.3	2.4
2016	**1.1**	1.4	1.8
2017	**1.2**	1.4	1.8
2018	**1.2**	1.1	1.7
2019	**0.9**	1.0	1.7
2020	**1.3**	1.8	2.1
2021	**1.5**	1.9	2.6

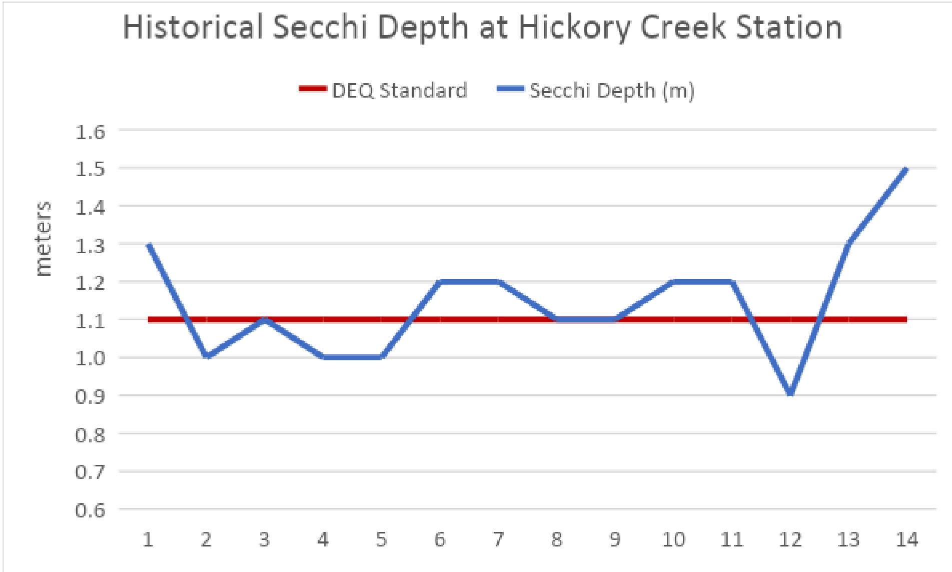


Figure 2-45. Historical Annual Average (Mean) Secchi Depth at Hickory Creek Station on Beaver Lake from 2008 through 2021.

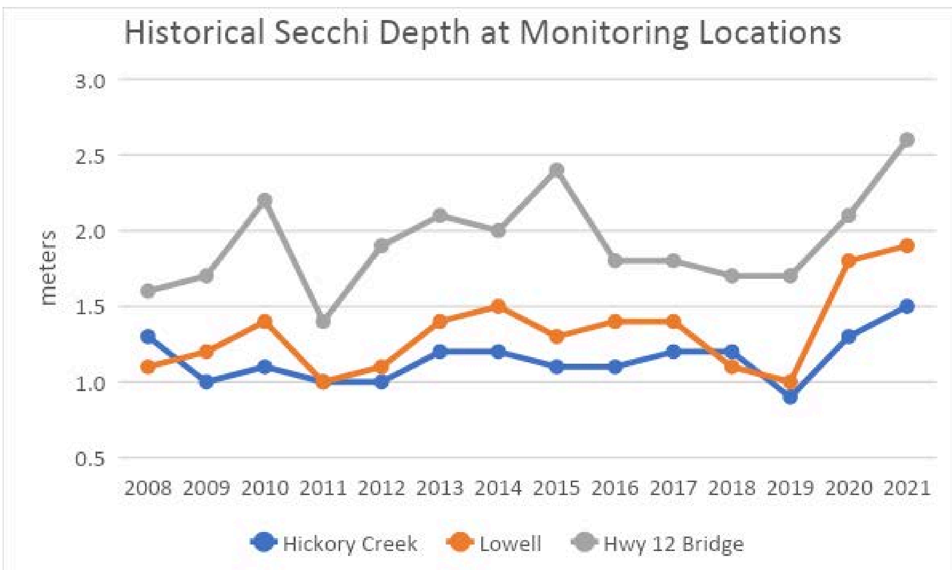


Figure 2-46. Historical Annual Average (Mean) Secchi Depth at Select Monitoring Locations on Beaver Lake from 2008 through 2021.

2.4 Priority Watershed Issues

Arkansas's DEQ provides a list of waterbodies not meeting water quality standards and or not supporting designated beneficial uses such as aquatic life, primary and secondary contact, drinking water supply, as well as other uses. The most recently approved list is from 2018.

TABLE 2-13. Approved 2018 303D Listed Waters for Planning Segment 4K and All Categories within the Beaver Lake Watershed (ADEQ website list, accessed January 26, 2023).

Reach Name	Reach	Miles Acres	Ecoregion	Beneficial Use	Parameters	Source	Priority
Beaver Lake, Hickory Creek	4042	865 ac	Ozark Highlands	Primary Contact	Turbidity, Pathogens	Surface Erosion	L
Beaver Lake, War Eagle Arm	4041	1,282 ac	Ozark Highlands	Primary Contact	pH, Turbidity, Pathogens	Surface Erosion, Unknown	L
Beaver Lake, White River Arm	4040	1,338 ac	Ozark Highlands	Primary Contact	Turbidity, Pathogens	Surface Erosion	L
Middle Fork White River	926	15.5 mi	Boston Mountains	Aquatic Life	Dissolved Oxygen	Unknown	M
West Fork White River	024	10.7 mi	Ozark Highlands	Other Uses	Sulfate, TDS, Turbidity	Unknown	L
West Fork White River	624	19.2 mi	Boston Mountains	Aquatic Life	Dissolved Oxygen, Sulfate	Unknown	M
White River	023	1.9 mi	Ozark Highlands	Other Uses	Turbidity	Unknown	L
White River	923	5.1 mi	Ozark Highlands	Other Uses	Turbidity	Unknown	L
Town Branch Fayetteville	824	3.0 mi	Ozark Highlands	Other Uses	Turbidity	Surface Erosion	L
Town Branch Huntsville	959	2.1 mi	Ozark Highlands	Domestic Water	Nitrate, TDS	Industrial, Municipal	L

The 2018 303D List was updated in 2020, but the list is still pending EPA's approval and is still considered draft at the time this information was accessed (January 26, 2023). Figure 2-47 gives a visual of the reaches fully supporting and not supporting designated beneficial uses covered by these waters provided by RTI International. However, Table 2-14 provides a comprehensive listing of all water bodies, i.e. DEQ reaches, listed in the 2020 draft 303D List across all categories, which corresponds to the initial revisions of the watershed protection strategy.

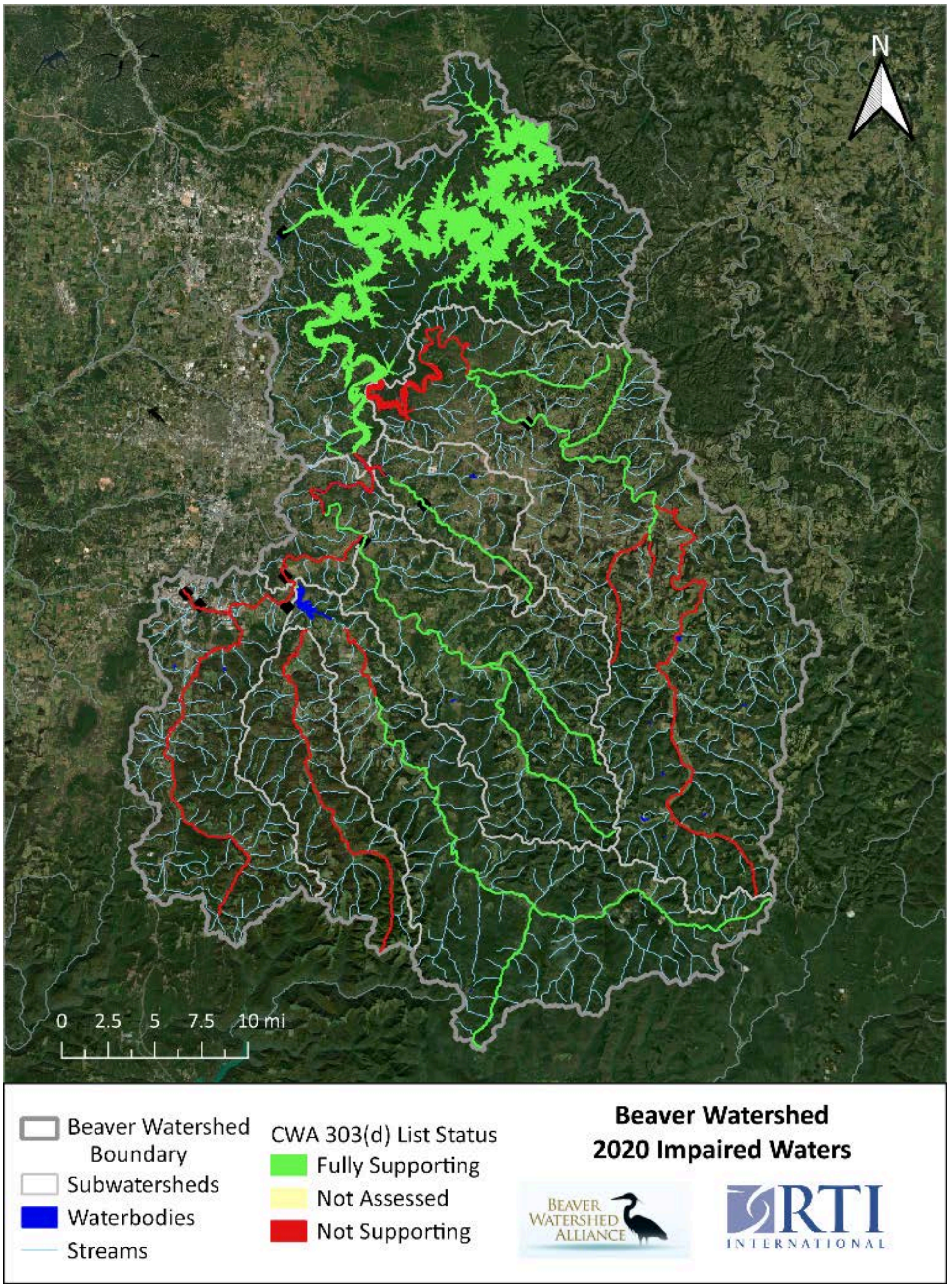


Figure 2-47. 2020 Clean Water Act Section 303(d) Listed Waters within the Beaver Lake Watershed.

TABLE 2-14. Draft 2020 303D Listed Waters for Planning Segment 4K and All Categories within the Beaver Lake Watershed (ADEQ website list, accessed January 26, 2023).

Reach Name	**Reach**	**Miles Acres**	**Ecoregion**	**Beneficial Use**	**Parameters**	**Source**	**Priority**
Beaver Lake, Hickory Creek	4042	865 ac	Ozark Highlands	Primary, Sec. Contact	Turbidity, Pathogens	Surface Erosion	L
Beaver Lake, War Eagle Arm	4041	1,282 ac	Ozark Highlands	Primary, Sec. Contact	Turbidity, Pathogens	Surface Erosion, Unknown	L
Beaver Lake, White River Arm	4040	1,338 ac	Ozark Highlands	Primary Contact	Turbidity, Pathogens	Surface Erosion	L
Middle Fork White River	026	8.1 mi	Ozark Highlands	Aquatic Life	Dissolved Oxygen (DO)	Unknown	L
Middle Fork White River	926	15.5 mi	Boston Mountains	Aquatic Life	DO	Unknown	M
West Fork White River	024	10.7 mi	Ozark Highlands	Aquatic Like	DO, Sulfate, Temp, TDS	Unknown	L
West Fork White River	624	19.2 mi	Boston Mountains	Aquatic Life	DO, Sulfate	Unknown	M
White River	023	1.9 mi	Ozark Highlands	Aquatic Life	DO, Turbidity	Unknown	L
White River	823	5.1 mi	Ozark Highlands	Aquatic Life	DO, Turbidity	Unknown	L
War Eagle Creek	060	33.7 mi	Ozark Highlands	Aquatic Life	DO	Agriculture, Unknown	L
War eagle Creek	834	19.6 mi	Ozark Highlands	Aquatic Life	DO	Agriculture, Unknown	L
Town Branch Fayetteville	824	3.0 mi	Ozark Highlands	Other Uses	Turbidity	Surface Erosion	L
Town Branch Huntsville	959	2.1 mi	Ozark Highlands	Domestic Water	Nitrate, TDS	Industrial, Municipal	L

Since the initial updating of this watershed protection strategy, Arkansas's DEQ also releases the 2022 draft 303D List. Various waterbodies or reaches bounce on and off the draft lists, based on the rolling assessment of data, water quality standards, and information available. While other waterbodies stay on the list, these appear on the approved and drafts lists, which show that these waterbodies are consistently not meeting applicable water quality standards and or designated beneficial uses for those specific water bodies.

TABLE 2-15. Draft 2022 303D Listed Waters for Planning Segment 4K and All Categories within the Beaver Lake Watershed (ADEQ website list, accessed January 26, 2023).

Reach Name	Reach	Miles Acres	Ecoregion	Beneficial Use	Parameters	Source	Priority
Beaver Lake, Hickory Creek	4042	865 ac	Ozark Highlands	Primary, Sec. Contact	Chlorophyll-a	Drinking Water Supply	L
Beaver Lake, War Eagle Arm	4041	1,282 ac	Ozark Highlands	Other Uses	Turbidity	Surface Erosion, Unknown	L
Middle Fork White River	026	8.1 mi	Ozark Highlands	Aquatic Life	Dissolved Oxygen (DO)	Unknown	L
Middle Fork White River	926	15.5 mi	Boston Mountains	Aquatic Life	DO	Unknown	M
West Fork White River	024	10.7 mi	Ozark Highlands	Aquatic Like	DO, Sulfate, Temp., TDS	Unknown	
West Fork White River	624	19.2 mi	Boston Mountains	Aquatic Life	DO, Sulfate	Unknown	M
White River	023	1.9 mi	Ozark Highlands	Aquatic Life	DO, Temp.	Urban, Agriculture, Municipal	L
War Eagle Creek	060	33.7 mi	Ozark Highlands	Aquatic Life	DO	Agriculture, Unknown	L
Town Branch Huntsville	959	2.1 mi	Ozark Highlands	Domestic Water	TDS	Industrial, Municipal	L

The approved and draft 303D listed waterbodies for the Beaver Lake watershed provide some relevance to what the true watershed issues are regarding designated beneficial uses, including aquatic life, drinking water supply, and primary and secondary contact. While waterbodies may move on and off the 303D list for this watershed, these 303D lists provide valuable information to establish watershed priorities relevant to this watershed protection strategy. Two things emerged from these 303D lists relevant to the modeling efforts used in this strategy, (1) the aquatic life and drinking water supply uses were impaired for chlorophyll-a and dissolved oxygen, and (2) other beneficial uses were impaired for turbidity.

The strategy can infer that chlrophyll-a and dissolved oxygen issues in these waterbodies result from nutrient inputs from the landscape, where these nutrients from the external sources increase algal growth resulting in exceedances in the chlorophyll-a WQS for Beaver Lake at Hickory Creek and potentially increase algal growth in stream reaches resulting in large diurnal swings in dissolved oxygen. However, where dissolved oxygen and water temperature are both listed as causal parameters then extreme low flows from changes in climate and hydrology, i.e. rainfall-runoff and its influence on seasonal base flow; sustained periods of low base flow might influence dissolved oxygen and water temperature dynamics resulting in violations of WQS. This observation provides evidence into the importance of focusing on nutrient inputs from the land scape from current and future scenarios.

The observation that turbidity was listed as a causal parameter suggests that sediments from surface and streambank erosion should be a focus of this watershed protection strategy. In fact, considering both the current and future conditions, sediment is the key parameter of concern in the coming decades, both for lake water quality and localized stream impacts. Lake protection actions taken to mitigate sediment loading should also address much of the projected increase in nutrient (mainly phosphorus but also nitrogen) loadings.

Specifically, pasturelands, manure applications, unpaved roads, and streambank erosion, among other sources, have quantifiable contributions to the sediment and nutrient load generation within the watershed and delivered to the lake. Pursuing restoration of pasturelands to oak savannah/prairie can result in localized and cumulative benefits, including reductions in peak flows and in sediment and nutrient loads. An in-depth scenario modeled through the District's Conservation Assessment Report confirms these findings (RTI International, 2022). Manure application rates coincide with areas of increased loading and are concentrated in certain areas of the watershed that can be approached for management of poultry operations and manure distribution (Section 3.2). Unpaved roads can be a significant source depending on local conditions (RTI International, 2022). Streambank erosion, while conservatively estimated by the model, was still shown to contribute significant amounts of sediment to Beaver Lake and is further emphasized by measurements conducted throughout the White River subwatersheds.

In addition to modeling results emphasizing the importance of addressing water quality in the region, during the most recent "Update of the Priority Watershed Matrix" conducted by FTN Associates, Ltd., the Beaver Reservoir HUC8 was identified as having the highest final risk rating in both 2010 and 2022 matrices. Along with other previous studies and analyses and stakeholder discussions, RTI identified the following priority actions for lake protection that address the two main pollutants of focus – ***sediments and nutrients*** – and maximize water quality benefits:

- Preserving and restoring vegetation and banks along stream buffers and stream channels, as well as conserving land in upland areas, to address sediment runoff, especially due to streambank erosion (Sections 4.2.2.1, 4.2.2.2 and 4.2.2.3)
- Enhancing pastureland management practices to address both sediment and nutrient runoff from agricultural and pastoral activities (Section 4.2.2.5)
- Improving manure management for animal operations to address nutrient runoff from agricultural activities (Section 4.2.2.6)
- Improving unpaved roads to address sediment runoff (Section 4.2.2.4)
- Managing the quality and volume of runoff from new development and construction site runoff to address sediment runoff (Section 4.2.2.5)
- Expanding education and outreach programs to address nutrient runoff from septic tanks and other sources (Section 4.2.3)
- Improving stormwater management and low impact development (LID) to address urban stormwater runoff (Section 4.2.2.9)

These actions and prioritized locations for action are discussed in further detail in Section 4.2.2, where key conservation practices for each of the major priority watershed issues are discussed.

Furthermore, improved water policy, nutrient management plans, and wastewater management as discussed in Section 3, can not only incentivize, and make way for these conservation practices to be implemented, but reduce the pollution loads that these priority actions need to address.

3 Building Blocks and Gaps for Lake Protection

A review of current regulations within the Beaver Lake watershed revealed several potential building blocks – and some gaps – for the Beaver Lake Watershed Protection Strategy. Efforts to protect and improve water quality within the watershed have been ongoing for decades. This section highlights three key water quality protection building blocks: water policy, nutrient management plans, and wastewater management. Gaps in these existing programs are also highlighted.

3.1 Water Policy

Water policy is one of the most critical building blocks in the watershed. Without it, many of the necessary protections for the lake would not exist. However, water policies, including codes and ordinances, are fragmented throughout the region. This creates difficulty for developers and contractors to build to standards as they differ from city to city. The standards surrounding tree preservation are a great example. In-stream regulations, such as gravel mining, are another example of the fragmentation of standards.

3.1.1 Local Stormwater Regulation

Stormwater discharges for large and medium size communities are regulated by federal Clean Water Act rules for the NPDES permit program but administered and enforced by DEQ. This program regulates all major discharges of stormwater (i.e., polluted runoff from municipal areas) to surface waters. The purpose of the NPDES permits is to reduce pollutants in stormwater runoff from certain municipal separate storm sewer systems (MS4s), construction sites, and industrial activities by requiring the development and implementation of stormwater pollution prevention plans and programs.

MS4s describe a "conveyance or system of conveyances" that collects stormwater separately (not a combined system) and is not treated at a sewage treatment plan or publicly owned treatment works (POTW) (U.S EPA, 2022); rather, the stormwater, which can pick up pollutants, flows untreated into local creeks, streams, and lakes. To protect these waterways, the DEQ has designated certain communities with MS4s as regulated stormwater dischargers and has issued a general permit with stormwater management conditions that all regulated MS4 communities must meet, including:

- Public education and outreach on stormwater Impacts
- Public involvement/participation

- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Post-construction stormwater management in new development and redevelopment
- Pollution prevention/good housekeeping for municipal operators

In the Beaver Lake Watershed, regulated small MS4 jurisdictions include portions of Benton County (including Prairie Creek), Washington County, Elkins, Fayetteville, Greenland, Lowell, Rogers, Springdale, and the University of Arkansas. These MS4 jurisdictions have contracted with the University of Arkansas System Division of Agriculture Cooperative Extension Service to develop and administer a Northwest Arkansas Urban Stormwater Education Program covering Benton and Washington counties, or the “Fayetteville-Springdale-Rogers” urbanized area. The program is designed to address the educational and outreach components in the above minimum control measures. This includes education and participation opportunities for the public, industries, businesses, and professional and civic organizations. The program also provides permit-required training for regulated MS4 employees.

In terms of designating regulated MS4 areas, regulated areas are based on the census survey every 10 years and determined by population density. Densely populated areas are called urbanized areas for the purposes of future stormwater regulation.[2] However, by the time the area has been designated as “urban,” a significant amount of uncontrolled stormwater runoff has been generated, which would not be covered by the regulations. In these situations, development designers do not always incorporate appropriate stormwater best management practices into their projects and the cities and counties can then be forced to deal with stream channel erosion, water quality degradation, and other consequences linked to rapid stormwater runoff; low rates of infiltration and groundwater recharge; and a general absence of stormwater pollution controls. Therefore, consultants need the training to choose the most appropriate Best Management Practices (BMPs) for each project and the contractors need to be trained to utilize them. The new federal EPA Construction General Permit will require Storm Water Pollution Prevention Plan (SWPPP) inspectors to complete eight hours of approved inspector training and hold current certification by 2023. This requirement could also be considered by the state or localities.

In terms of construction phase impacts, federal stormwater regulations require that all construction sites disturbing more than one acre, regardless of their location, must have sedimentation and erosion controls. A site of one acre or more must also have a SWPPP on site,

[2] It is not a direct correlation between an urbanized areas and MS4 regulation, as explained by the Stormwater Phase II Final Rule: https://www3.epa.gov/npdes/pubs/fact2-1.pdf

and once the site size exceeds five acres, it must be filed with DEQ. If this land disturbance falls outside of a designated MS4 community, the Arkansas Department of Energy and Environment - Water Quality is required to administer and enforce the stormwater NPDES requirements unless a local government voluntarily enacts an ordinance. However, the state does not have adequate resources to enforce these requirements. Overall, champions at high levels of government and community must see the need for erosion and sediment control to generate change in the regulatory arena. Another identified gap is the relative absence of enforcement of the construction phase stormwater rules. Lastly, funding and acceptance of water quality monitoring stations is needed to document stream impacts. The data from these stations can facilitate the creation of targeted stormwater action plans.

Arkansas Department of Transportation (ARDOT) construction projects, facilities, and roadway drainage systems owned and managed by ARDOT must comply with the federal and state stormwater permitting and management regulations discussed previously. Roads, ditches, and drainage ways on ARDOT-owned property fall non-traditionally under the MS4 stormwater permitting program. As a nonregulatory state agency, ARDOT's enforcement powers against outside entities are limited. ARDOT may seek the assistance of the MS4 operator to resolve stormwater concerns when within the boundary of another regulated small MS4 system but discharging into ARDOT property. When the stormwater concern is outside the MS4 boundary, ADEQ enforcement or Arkansas Department of Health will be contacted for resolution. ARDOT construction activities with a disturbed area of one acre or more are regulated by the DEQ Construction Stormwater General Permit (ARR150000) and ARDOT maintenance facilities, materials storage yards, existing roadways, and drainages are regulated by the statewide MS4 permit (ARR040000). Both permits require the reduction of stormwater impacts on surface waters through the following enforceable permit requirements:

- Requirement to implement and maintain appropriate erosion and sediment control BMPs
- Requirement to control waste such as discarded building materials, concrete truck washout chemicals, litter, and sanitary waste at construction sites that cause adverse impacts to water quality
- Procedures for site plan review that incorporate consideration of potential water quality impacts
- Procedures for receipt and consideration of information submitted by the public
- Procedures for site inspection and enforcement of control measures.

The DEQ construction stormwater general permit requires that permittees/operators (property owners, general contractors, etc.) of construction sites disturbing one acre or more must develop and implement a SWPPP, conduct routine site inspections, and maintain BMPs until site stabilization is complete.

The DEQ Stormwater Program has greatly improved since 2008. The DEQ was operating under the initial stormwater management plan created in 2006. BMPs have changed significantly and training programs for both staff and contractors working on ARDOT jobs are well developed and robust. The DEQ Stormwater Program has grown and changed significantly from a few BMPs to incorporating multiple BMPs as technology has advanced. Some codes and ordinances that are good examples of Low Impact Development (LID) and in-stream policy include:

- The City of Fayetteville's Title XV Unified Development Code, Chapter 179- Low Impact Development; this chapter provides a regulatory basis for site design and development that incorporates LID strategies into land development.
- The City of Fayetteville's 168.12 Streamside Protection Zones Ordinance, outlining streamside protection zone requirements, as well as regulated uses, structures, and activities within streamside protection zones.
- The City of Roger's Drainage Criteria Manual, summarizing submittal requirements for plans and drainage reports to the city, stormwater planning, and various drainage project design guidelines.
- The City of Rogers' Sec. 14-2. Cave Springs area karst resource conservation regulations. While the Cave Springs area is in the Illinois River Watershed, these regulations apply to the direct recharge areas of the City of Rogers, City of Springdale, City of Lowell, and City of Cave Springs, and aim to protect water quality of the Cave Springs recharge area to protect the aquatic habitat.
- The City of Goshen's Ordinance No. 157: Regulate Landscaping in Commercial Districts within the City and for Other Purposes. This ordinance establishes regulations concerning landscaping with the aim of preserving trees, increasing tree canopy, creating healthier environments by decreasing chemicals and sediments entering water supplies, and reducing nonnative plants, among others.

The primary gap for these examples continues to be their enforcement.

3.2 Nutrient Management Plans

The Beaver Lake Watershed has been designated as a Nutrient Surplus Area under Arkansas Acts 1059 and 1061 of 2003, as implemented by Title XXII of the Arkansas Department of Agriculture - Natural Resources Division (ANRD) Rules Governing the Arkansas Soil Nutrient and

Poultry Litter Application and Management Program, effective January 2006. The purpose of these rules is to maintain the benefits derived from the wise use of poultry litter and other soil nutrients, while avoiding undesirable effects from excess nutrient applications on the waters of the state. Requirements for soil testing, recordkeeping, placement and timing of litter application, and other elements of nutrient management plans are specified in the rules. Although the rules require the maintenance of records for five years and require their availability for inspection by ANRD or Conservation District employees, there is no opportunity for review by other agencies or by the public.

Specifically, *Act 1061: An Act to Require Proper Application of Nutrients and Utilization of Poultry Litter in Nutrient Surplus Areas* requires that:

- All nutrient applications on residential and nonresidential development exceeding 2.5 acres in a Nutrient Surplus Area must be done according to a Nutrient Management Plan.
- Applications within a Nutrient Surplus Area on residential lands of 2.5 acres or less shall be applied at a rate not to exceed a protective rate (as defined in Title XXII).
- Nutrients may be applied only by a certified nutrient applicator if within Nutrient Surplus Areas, except on residential lands of 2.5 acres or less.
- The landowner is responsible for maintaining documentation of the nutrient application in accordance with their plan.
- Poultry feeding operations within a Nutrient Surplus Area shall develop and implement a poultry litter management plan acceptable to ANRD.
- The poultry litter management planner shall be certified by the ANRD.

Additional legislation supports Act 1061, including:

- *Act 1059:* Arkansas Soil Nutrient Management Planner and Applicator Certification Act, which requires the certification of persons to properly develop nutrient management plans or to properly supply soil nutrients and requires ANRD to develop and implement a nutrient management education, training, and certification program.
- *Act 1060:* An Act to Register Poultry Feeding Operations, establishes annual registration with ANRD of poultry feeding operations where more than 2,500 poultry are housed or maintained.

Nutrient management plans for poultry litter in the Beaver Lake watershed are currently estimated using the Arkansas P index, which bases application rates on crop nitrogen requirements when a site is in the low or moderate risk category for phosphorus loading. It should be noted that there are more recent discussions on the use of the index due to its lack of consideration of karst and local conditions (Democrat-Gazette, 2019; Walkenhorst, 2019).

Interviews with resource agencies and poultry integrators suggested a high level of compliance with the Nutrient Management Plan requirements. Based on this, it is assumed that Nutrient Management Plan implementation is in effect now and will continue for applicable lands. Without such long-term compliance, the lake protection goals would not be achieved. Thus, the Strategy emphasizes the importance of maintaining high compliance with Nutrient Management Plan requirements.

3.3 Wastewater Management

The Clean Water Act requires the control of wastewater discharges to surface waters under the NPDES program. Arkansas's DEQ, the delegated authority to administer the program, issues permits to treated effluent dischargers with limitations on wastewater flow and pollutants in order to protect surface water quality and the beneficial uses of the water. These permits must be renewed by dischargers every five years. Dischargers must also obtain a permit from DEQ to construct any waste collection, treatment, or discharge facility to ensure that proper engineering design is used; dischargers are also required to perform self-monitoring. As of December 2016, NPDES permittees must submit discharge monitoring reports online using the NetDMR tool. Those records, along with periodic inspections and monitoring by DEQ, are used to determine compliance with permit requirements. Enforcement measures, including fines and revoking permits, are available to DEQ when addressing noncompliance by dischargers.

Currently, there are two major, active NPDES permits to discharge wastewater within the watershed (Fayetteville's Noland Plant and Huntsville's Plant), and several minor effluent, discharge permits near Beaver Lake and West Fork (Table 3-1; Section 2.2.1.1). Much of the municipal wastewater is generated along the far western boundary of the Beaver Lake drainage area, in the cities of Fayetteville, Springdale, Lowell, Rogers, and Pea Ridge, which lie south-to-north along US 71. These cities are served mostly by the centralized WWTPs that discharge to surface waters of the Beaver Lake and the Upper Illinois watersheds, but adjacent subdivisions are increasingly served by smaller clustered (decentralized) facilities that discharge to the soil. Outlying and rural areas of the watershed are served mostly by individual or small clustered systems with soil discharges.

Table 3-1. Communities in the Beaver Lake Watershed Area and their Drinking Water and Wastewater Utilities*

Town (Population and Size Rank in Arkansas)	Drinking Water Utility	Wastewater Utility
Fayetteville (86,751 - #3)	Beaver Water District	Fayetteville (discharge to White River and Illinois River)
Springdale (81,029 - #4)	Beaver Water District	Springdale (discharges to Illinois River)
Rogers (67,600 - #6)	Beaver Water District	Rogers (discharges to Illinois River)
Elkins (3,179 – #100)	Fayetteville	Fayetteville
West Fork (2,635 – #114)	Fayetteville	Fayetteville
Huntsville (2,554 – #116)	MCRWD	Huntsville
Prairie Creek (2,150 - #135)	Beaver Water District	Septic
Goshen (1,879 - #148)	Fayetteville	None – septic systems
Greenland (1,434 - #169)	Fayetteville	Fayetteville
Avoca (520 - #272)	BWRPWA	Septic
Garfield (576 - #256)	BWRPWA	Septic
Gateway (474 - #285)	BWRPWA	Septic
Winslow (427 - #427)	Lake Fort Smith	Septic
Lost Bridge Village (416 - #301)	BWRWPA	Package Wastewater Treatment Plant
St. Paul (104 - #436)	Beaver Water District/MCRWD	Septic
Hindsville (65 - #459)	MCRWD	Septic

* While Elkins, West Fork, Goshen, and Greenland buy their water from Fayetteville, the source of that water is Beaver Water District.

The Noland and Westside plants have continued to upgrade systems, specifically SCADA instrumentation, electrical systems, and equipment as needed to maintain plant reliability. Many electrical components continue to evolve over time and require upgrades to remain current with emerging technology. Since 1990, the City of Fayetteville's Noland WWTP has had a discharge permit limit of 1.0 mg/L for TP for discharge to the White River. There has also been a large drop in phosphorus load from the City of Huntsville over the last 10 years.

The Strategy highly recommends continuance of the state regulation of phosphorus concentration through effluent limitations for the larger wastewater discharge permits. It is important to note that the City of Fayetteville and the District have an Agreement for the Protection of the Beaver Lake Watershed whereby Fayetteville maintains an average TP discharge concentration of 0.5 mg/L year-round and will not exceed 93.4 pounds per day of TP from July through October. The City of Fayetteville has taken several major steps to implement the Agreement and has in recent years discharged less than 4,000 pounds of phosphorus each year into the White River, with some years less than 3,000 pounds. In addition, the City of Fayetteville has made commitments to reduce nonpoint source loading of TP.

In addition to loads from WWTPs, malfunctioning individual residential wastewater (septic) systems may be causing localized surface water quality problems in some areas. Wastewater treatment systems discharging to the soil can pose a threat to the White River, the lake, and its tributaries in areas where high densities of older, heavily used systems are near surface streams or karst topography. Current rules specify the types of legally acceptable tanks, infiltration system components, and other devices, and provide for evaluation of the installation site, training and licensing of service providers, and the management of systems that serve multiple homes or other facilities. Individual home wastewater treatment systems in Arkansas are regulated by the Arkansas Department of Health (ADH) if they discharge to the soil on the system owner's property. Systems that discharge to the soil offsite, to a surface waterbody, or to soil onsite with flows greater than 5,000 gallons per day are regulated by DEQ under its NPDES discharge permit and other programs. In general, ADH will approve individual home systems with septic tanks and soil absorption fields if adequate space is available, soils are suitable (i.e., acceptable percolation rate), and setbacks can be met from groundwater tables, wells, public water supply intakes, streams, lakes, ponds, property lines, etc. Drain fields are sized in accordance with soil percolation rates: the slower the percolation rate, the larger the required drain field.

Individual wastewater systems require regular maintenance, such as pumping every 3 to 5 years, to function as designed. There are no provisions for checking or reporting maintenance or malfunctioning systems. A monitoring program can help detect elevated bacteria and trace sources of problems. Such monitoring would be particularly important in Beaver Lake's coves and associated tributaries.

While the District does not currently routinely monitor specifically for septic influence, they have undergone short-term investigations in selected areas. For example, the District recently (2021) performed an optical brightener study to investigate septic influence in Beaver Lake but were unable to reach any definitive conclusions concerning septic influence. Additionally, the District has monitoring programs in the watershed and at three lake sites where they do bacteria sampling but given the multitude of factors that contribute to bacteria load, changing values cannot be specifically attributed to septic influence.

ANRD invested in a program to repair and replace failed septic systems (across the entire HUC8 watershed, which is ~50% Beaver Lake watershed). While monitoring data are scarce, the state agencies recognize that failing individual septic systems pose a threat to water quality and are actively addressing these sources. An amount of $1 million is allocated to repairs and replacements over three years (2021-2023). Also, Washington County has an ordinance on the books for septic inspections. Ordinance 37 of 2003 requires point of sale inspections for homes in unincorporated areas of the county. However, there are limitations to the effectiveness of this ordinance. For example, the ordinance only requires a walk-through inspection. The location of a system may not be known, and vacant lots may be inspected as they are, meaning the system may not be running when the inspection takes place. Further enhancements to the monitoring program, and improvements to Ordinance 37 are recommended in this Strategy as well as enhanced landowner education regarding wastewater treatment and system maintenance.

3.4 Summary

It is important to note that this Strategy does not recommend phosphorus regulations that are more stringent than those of DEQ. Of the municipalities that are MS4 permittees, most have done well at implementing the education component of the permitting requirements. On the other hand, other requirements of the MS4 permits have been implemented with less success. At all levels (cities, counties, and the state), lack of resources was cited as a reason for the lack of enforcement or conformity to MS4 requirements. The function of this Strategy is to highlight these gaps and suggest solutions, but it is the responsibility of the municipality to conform to and enforce the requirements of their respective permits.

There are several major building blocks for the Strategy. The DEQ has issued stormwater permits for highly populated urbanized areas in Washington and Benton Counties. This requires a local regulatory mechanism for erosion and sediment controls and enforcement capability, and a program to address stormwater runoff from new development and redevelopment after construction has been completed.

In terms of MS4 education, there is education programming for contractors and developers, but more is needed at the local government level for city council, planning, and engineering departments to increase awareness on water quality and management issues in the watershed, as well as available solutions to address them. Also, the DEQ/state minimum requirements do not cover a significant amount of development in urbanizing areas within the lake drainage area. For other counties, DEQ has construction site management requirements for activities disturbing greater than one acre. Currently there is a significant gap in DEQ inspection and enforcement. Filling these gaps to carry out the existing stormwater management regulations as intended is recommended under the Strategy.

The State Nutrient Management Plan requirements for farmlands appear to have a high rate of compliance according to Soil and Water Conservation Districts. Agricultural landowners have increased their knowledge and participation in nutrient reduction strategies significantly since 2009. Nutrient reduction around developed areas remains a challenge as new residents move into the region. Education and outreach to new and existing residents remain important to encourage residents to test their soil and reduce phosphorus fertilizers, excess nutrients, and other nonpoint source pollutants to comply with the State Nutrient Management Plan. Continued compliance is essential in meeting the lake protection goals.

Protective phosphorus limits on municipal WWTPs are needed to meet the lake protection goals. As the smaller WWTPs plants expand, it will be critical for DEQ to require at least the same protective limits as those currently at the Noland Plant to meet the lake protection targets.

4. Proposed Beaver Lake Watershed Protection Strategy

The building blocks listed in the preceding section are the foundation for the Strategy described below. Measures that address the gaps in watershed protection and further enhance efforts to reduce nutrient and sediment inputs to the lake are the focus of the proposed approach.

4.1 Overview of the Updates to the Beaver Lake Watershed Protection Strategy

The initial Strategy written in 2012 included five complementary components:

- **Beaver Lake Watershed Council**: A diverse group representing different interests that provide sustained leadership for lake and watershed protection, including the facilitation of the implementation and adoption of the Beaver Lake Watershed Protection Strategy.
- **Core Best Management Practices (BMPs):** Voluntary BMPs that reduce sediment and phosphorus load to the lake and help reduce current sediment loading in existing impaired streams.
- **Developer and Lake Contractor Certification Program**: For local governments, site design engineers, developers, and contractors willing to implement protective stormwater controls for new development in the Municipal Planning Area and sign a Lake Protection Pledge.
- **Education and Stewardship Program**: Community outreach to teach property owners about lake protection efforts and how they can help.
- **Monitoring and Adaptive Management**: To address uncertainty and changing conditions and provide early warning signs for needed changes.

In consultation with the Alliance TC, the following changes to the five complementary components were recommended (Table 4-1).

Table 4-1. Beaver Lake Watershed Protection Strategy: Previous 2012 vs. Current Strategy Sections

2012 Strategy Components of Protection	2023 Strategy Update
Component #1: Beaver Lake Watershed Council	Overview of Beaver Watershed Alliance and its Current Mission
Component #2: Core Best Management Practices	Conservation Practices
Component #3: Developer and Contractor Lake Protection Certification Program	Education and Outreach
Component #4: Education and Stewardship Program	
Component #5: Monitoring and Adaptive Management	Monitoring and Adaptive Management

4.2 Four Components of the Updated Protection Strategy

4.2.1 Component #1 – Beaver Watershed Alliance

Stewardship and protection of the Beaver Lake watershed depends on the organized, collective, targeted efforts of citizens, businesses, property owners, managers, nongovernmental organizations (NGOs), and governmental agencies. In 2011, the Alliance was formed through a stakeholder-led process. The mission of the Alliance is “to proactively protect, enhance and sustain water quality in Beaver Lake and the integrity of its watershed.” The purpose of the Alliance is to provide sustained leadership, ensure that the partnership is strong, coordinate protection practices, and allocate resources necessary to implement Strategy recommendations as needed. In the context of the overarching goal of minimizing regulations, the Alliance’s function will be to implement educational and voluntary programs. The Alliance will also ensure meaningful public participation in decision-making. Any changes in the functionality of the Alliance will be at the discretion of the Board of Directors. Watershed management should be adaptive—a living process that responds to changing conditions, needs, and information. The Alliance can facilitate an approach that can adapt to changing needs and will allow current and future issues to be addressed in ways that are both environmentally sound and fiscally responsible. It is an approach in which all stakeholders can pool and coordinate their technical and financial resources to achieve the watershed management goals.

Mission

To proactively protect, enhance and sustain the water quality of Beaver Lake and the integrity of its watershed.

The Alliance does not have regulatory authority. Rather, it serves as a local nonprofit organization allowing interested parties to work together, carry out mutually beneficial projects, track progress, and make recommendations as needed. It is important to recognize that expert organizations exist that would logically be partners or leaders in specific Strategy components, such as conservation practice implementation. The Alliance will actively identify and fill gaps in implementation or programming and facilitate the execution of the Strategy.

4.2.2 Component #2 – Conservation Practices

There are several key conservation practices to focus on to obtain the goals and objectives of the Strategy. These conservation practices are highlighted in Table 4-2 and detailed in the following sections.

Table 4-2. Outline of Conservation Practices for the Beaver Lake Watershed Protection Strategy

Pollutant of Focus	Source	Corresponding Conservation Practice
Sediment	Cropland	Pasture Land Management (4.2.2.6), Land Restoration (4.2.2.2) and Conservation (4.2.2.1)
	Streambank Erosion	River Restoration, Streambank Restoration, and Stream Stabilization (4.2.2.3), Conservation within Upland Areas (4.2.2.1)
	Unpaved Roads	Unpaved Road Improvements (4.2.2.4)
	Construction Sites	Improved Construction Site Management (4.2.2.5), Conservation (4.2.2.1)
Nutrients	Cropland, Agricultural Runoff	Pastureland Management (4.2.2.6), Agricultural Ponds (4.2.2.7), Manure Management for Animal Operations (4.2.2.8)
	Septic Tanks	Increased Education and Outreach (4.2.3)
	Urban Stormwater Runoff	Improved Stormwater Management and LID (4.2.2.9)

4.2.2.1 Land Conservation

Conservation Easements

A conservation easement is the primary tool for voluntary, private land conservation. Conservation easements are legal agreements that limit development and subdivision of a property and restrict certain activities to protect the land's conservation values. The conservation easement stays with a property when the land is sold or transferred to subsequent owners. Conservation easements require a qualified easement holder, such as a land trust or government entity, to monitor and enforce the terms of the easement.

Easements can be achieved through donation or purchase. Currently, there are federal and state tax incentives for donating conservation easements. Conservation easements that meet Internal Revenue Code section 170 (h) criteria are treated as charitable gifts and the donation may qualify as a charitable tax deduction on the donor's federal income tax return. The Arkansas Wetland and Riparian Zone Tax Credit is a state tax incentive that applies to conservation easements that include wetland and riparian areas. NRCS's Agricultural Conservation Easement

Program (ACEP) provides financial assistance for purchasing agricultural land easements and wetland reserve easements for eligible lands.

For conservation easements, successful land conservation also requires long-term stewardship funds set aside for maintaining the easement in perpetuity and covering any legal expenses after the easement has been executed. Nongovernmental easement holding entities can demonstrate long-term viability by becoming accredited by the Land Trust Accreditation Commission.

Northwest Arkansas Land Trust (NWALT) is an accredited land trust based in Northwest Arkansas that has identified the Beaver Lake Watershed as a priority focus area. In 2020, NWALT created a Conservation Priority Index (CPI) to help identify priority lands in the Beaver Lake Watershed and actively works with landowners to complete perpetual conservation easements in strategic areas that advance source water protection. The CPI was developed for NWALT's Strategic Land Protection Plan (NWALT, 2020), with guidance from the Savannah River Watershed Management Initiative White Paper (Krueger & Jordan, 2014). These priorities in Figure 4-1 are calculated by NWALT and indexed to each parcel by the Alliance. The organization also owns lands in fee-simple and manages the lands as preserves.

Ozark Land Trust is an accredited land trust based in Missouri, but this organization has a vested interest in protecting lands through the Ozark region in Arkansas and Missouri, potentially including the Beaver Lake Watershed. This organization has been instrumental in protecting many natural landscapes and geological features throughout the Ozark region, using conservation easements, nature preserves, and partnerships with other organizations.

As of 2018, the District owned approximately 300 acres immediately surrounding the raw water intake, which is maintained mostly in native forest. The District also supports NWALT and the Ozark Land Trust to conserve properties of environmental significance within the watershed. In this program, the District provides funding to the land trusts for perpetual stewardship of conservation easements. The District's 2018 Source Water Protection Plan Update set an ongoing action to acquire 500 acres per year in conservation easements within the District's Source Water Protection area under the Landwise Program (Beaver Water District, 2018).

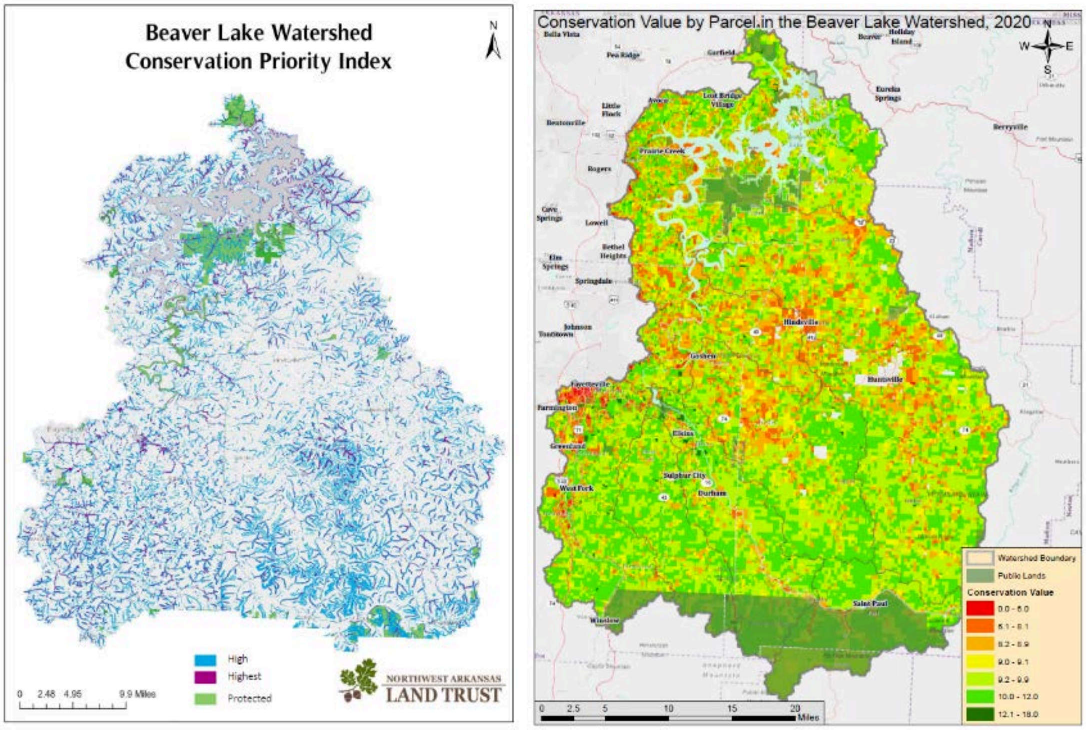


Figure 4-1. Beaver Lake Watershed Conservation Priority Index
Maps Show the CPI as Calculated by the NWALT (left) and Indexed to Each Parcel (right); Sources: NWALT, 2020 (Left), Alliance, 2020 (Right)

Conservation Agreements

In both the conservation easement and conservation agreement programs, there are financial incentives and rewards for businesses and landowners to establish conservation areas. Easements or agreements prohibit development or any disturbance of vegetation within the easement area, while providing the landowner continued use of the property. For conservation easements, successful land conservation also requires stewardship funds set aside for maintaining the easement in perpetuity and covering any legal expenses after the easement has been purchased.

To determine areas of greatest conservation area priority, those catchments with WaterFALL-modeled mean annual runoff, as well as locally generated, normalized sediment and nutrient (phosphorus and nitrogen) loads below the 25th percentile were weighted together evenly for both baseline and future (future land use and projected wet warm climate) scenarios (Figure 4-2). Those catchments with scores of 25 or less (light yellow) had only one priority below the 25th percentile, whereas those catchments in the 76-100 bracket (dark red) had all four metrics below the 25th percentile. Those lands immediately surrounding Beaver Lake, as well as in the headwaters of the White River, Brush Creek, and War Eagle Creek have the greatest conservation priorities. For the future scenario, priority areas increase in the upper Middle Fork and East Fork of the White River.

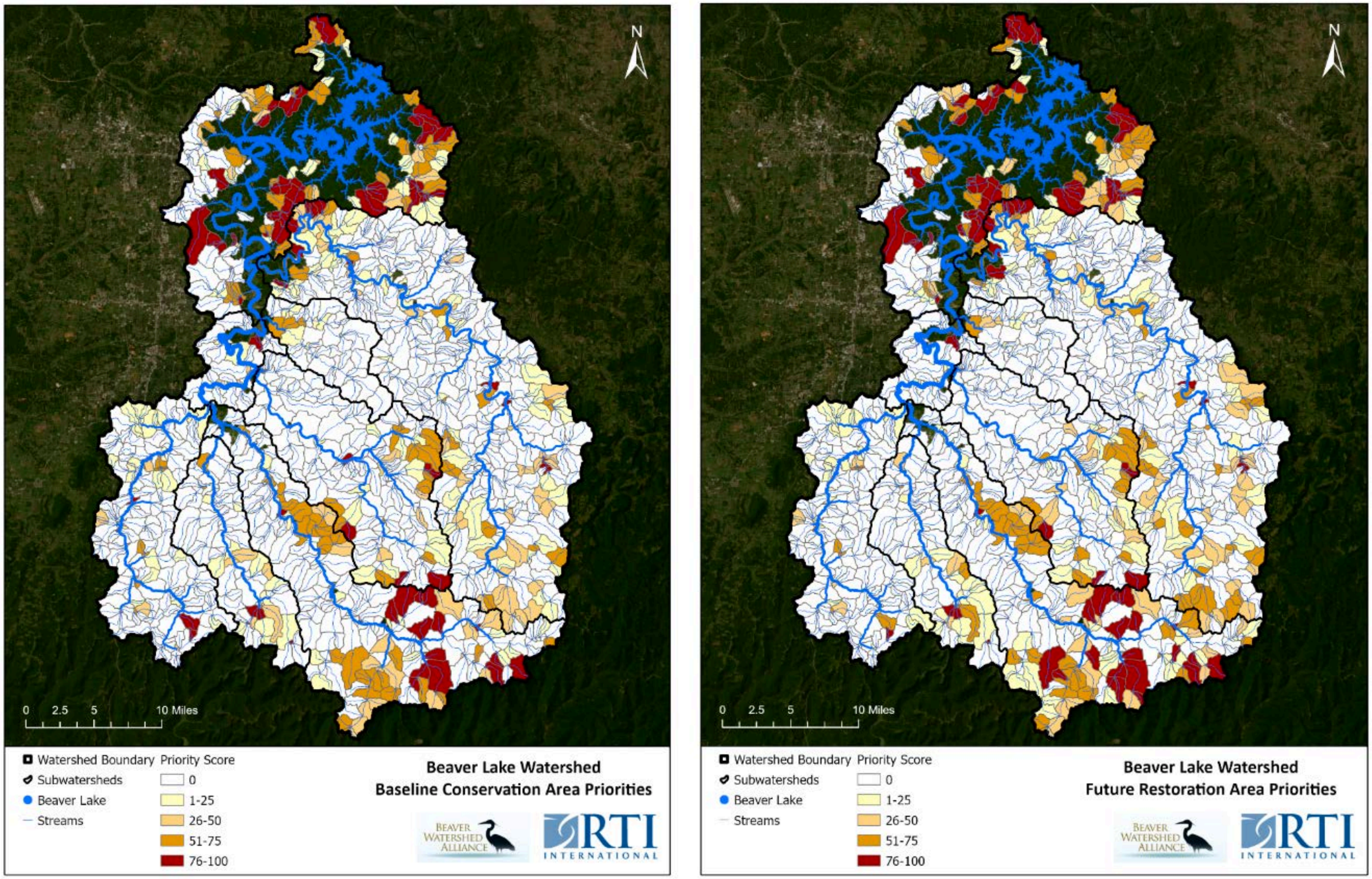


Figure 4-2. Conservation Area Priorities for Baseline (left) and Future (right) Scenarios for the Beaver Lake Watershed, based on WaterFALL Model Outputs for Runoff and Loads of Sediment, Nitrogen and Phosphorus.

4.2.2.2 Land Restoration

Unlike land conservation, which seeks to protect the lands as they currently exist, land restoration requires physical action to restore the land cover to a higher-quality state, in terms of ecological function, than what currently exists. By improving the quality or type of vegetative cover, these actions also produce hydrologic and water quality benefits in the form of decreased runoff and sediment and nutrient loads.

Land restoration may include, based on WaterFALL modeling:

- Riparian buffer, bank restoration, and stream restoration
- Improved construction site management
- Pastureland management
- Manure management for animal operations
- Improved stormwater management and LID
- Unpaved road improvements
- Forest and native land conservation and management

Funding for land restoration can be found through local, state, and federal grant programs, USDA Natural Resources Conservation Service programming, U.S. EPA programming, foundations, and support from local communities, businesses, and industries.

To determine areas of greatest restoration area priority, those catchments with WaterFALL-modeled mean annual runoff, as well as locally generated, normalized sediment and nutrient (phosphorus and nitrogen) loads above the 75th percentile were weighted together evenly for both baseline and future (future land use and projected wet warm climate) scenarios (Figure 4-3). Those catchments with scores of 25 or less (light yellow) had only one priority above the 75th percentile, whereas those catchments in the 76-100 bracket, represented in dark red, had all four metrics score above the 75th percentile. Figure 4-3 shows that those lands on the western edge of Beaver Lake, as well as in the lower Brush Creek, Richland Creek, and War Eagle Creek have the greatest restoration priorities. For the future scenario, priority areas increase in the White River subwatersheds. Lands in the Lower White and West Fork subwatersheds have an additional priority due to TMDL requirements.

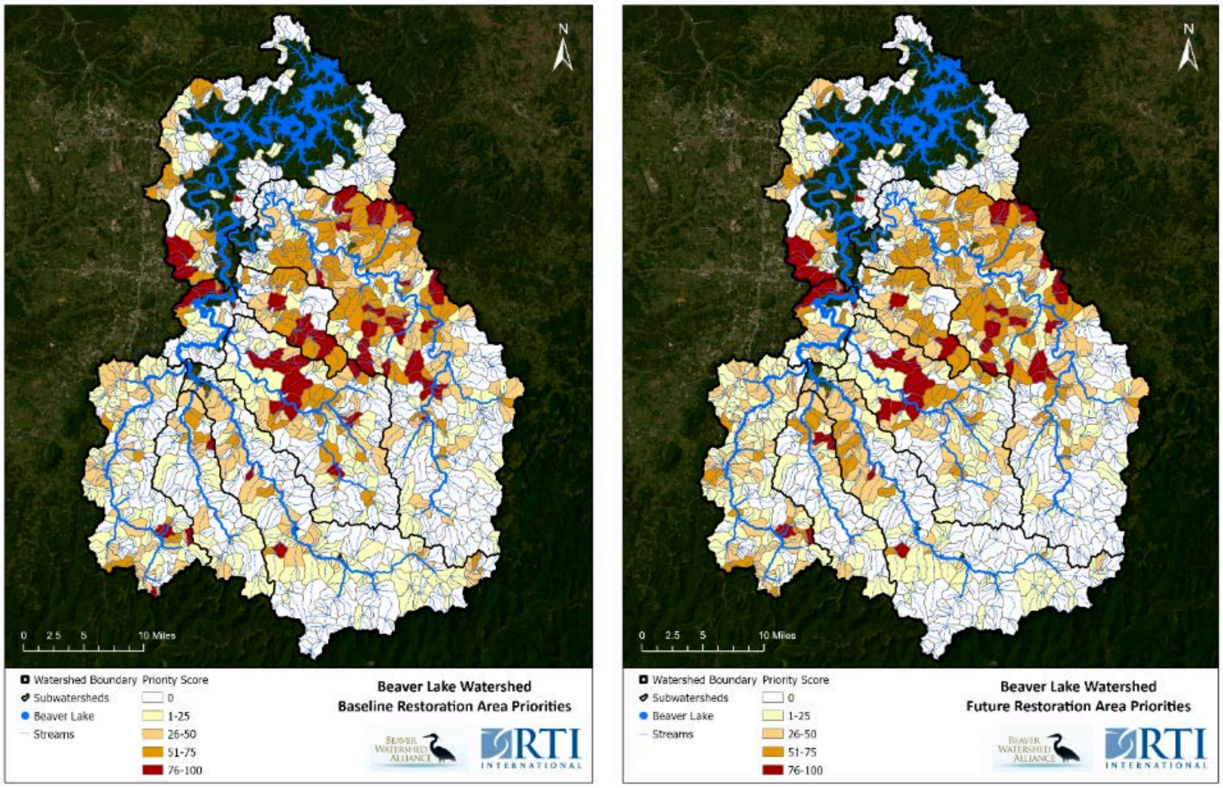


Figure 4-3. Restoration Area Priorities for Baseline (left) and Future (right) Scenarios for the Beaver Lake Watershed, based on WaterFALL Model Outputs for Runoff and Loads of Sediment, Nitrogen and Phosphorus.

In a response to the District's priorities for conservation, pasture land parcels that included riparian buffer areas were deemed priority locations for restoration due to combined benefits in sediment and nutrient load reductions from managing the land cover both within upload pasture lands and within the riparian buffer region surrounding the stream channels. These areas were selected through a GIS analysis. Parcels in the region that were greater than 40 acres and had a majority land cover (NLCD) of Pasture were first identified. The 40-acre threshold was set to identify parcels in which restoration activities would be large enough to produce noticeable benefits within a single area and with a single landowner. Then, those large pasture parcels that were within a 30-meter buffer of the NHDPlus flowline (i.e., contained riparian buffer area) were selected as shown in Figure 4-4. The length of the NHDPlus flowline that is included within these riparian parcels is also shown in Figure 4-4. It should be noted that this method cannot identify if pasture management BMPs are already in place, rather, it highlights those areas where they should be emphasized. These identified parcels, representing large pastureland areas that also border a stream reach, can then be compared to the priority catchments identified as areas of greatest restoration priority (Figure 4-3) to create an initial targeted list of landowners to approach or specific land areas to further assess for development of restoration or management actions.

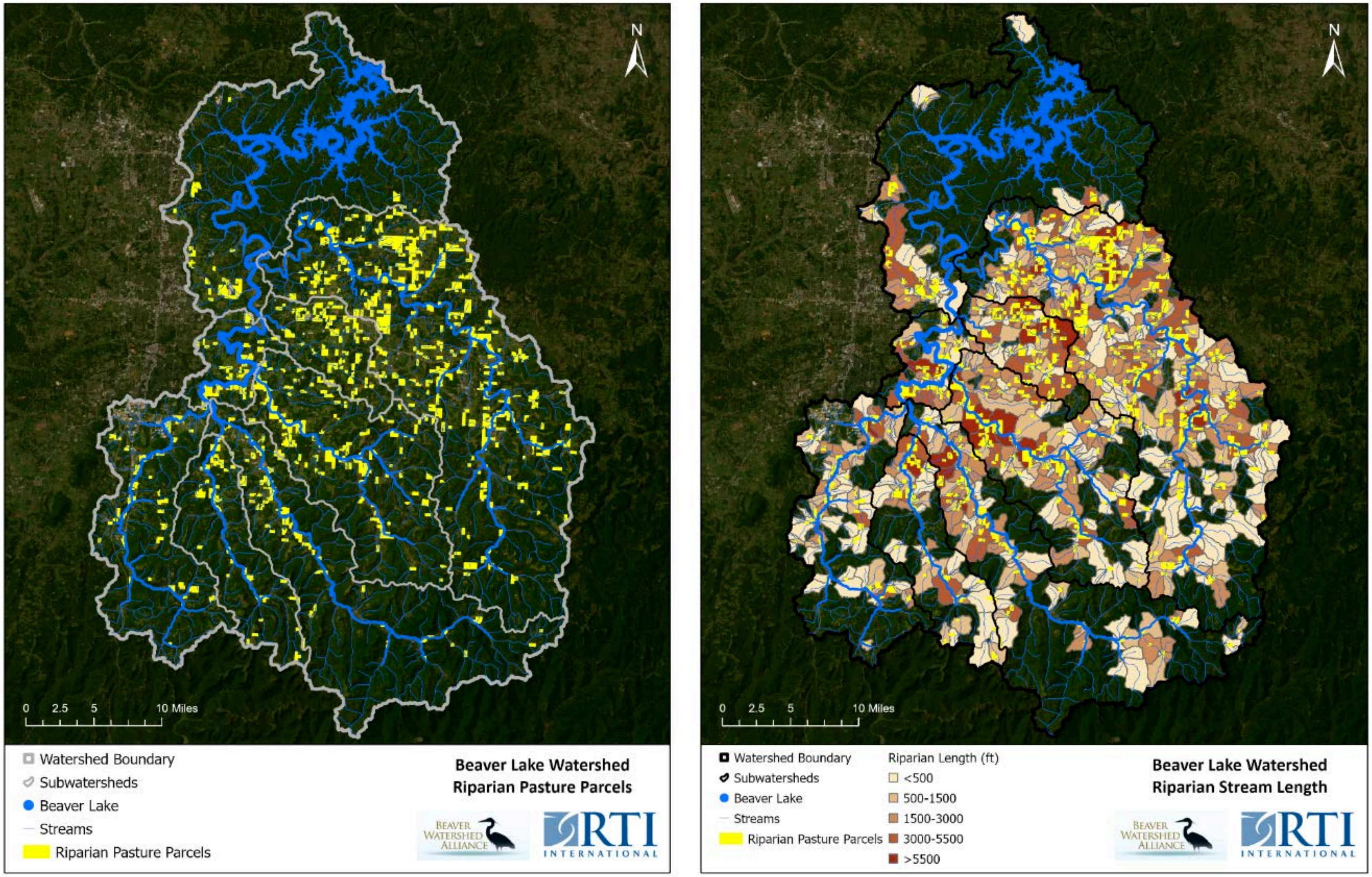


Figure 4-4. Majority Pasture Riparian Parcels (left) Overlayed with the Corresponding Riparian Stream Length through These Parcels (right) across the Beaver Lake Watershed.

4.2.2.3 River Restoration, Streambank Restoration, and Stream Stabilization

This section was contributed by Sandi Formica and Matthew Van Eps from the WCRC.

An effective method of addressing channel instability that has frequently been applied in the Beaver Lake watershed is stream restoration based on natural channel design (NCD) principles rooted in hydrologic, hydraulic, geomorphic, vegetative, and erosion/sediment processes. This method is useful for developing restoration designs for unstable sections of river and individual streambanks. Implementation of NCD-based projects helps restore the local ecology and improve water quality, while reducing streambank erosion. Addressing accelerated streambank erosion utilizing only bank stabilization techniques, such as riprap toe protection, does not necessarily provide a long-term solution to the problem or significantly enhance the river ecology. The potential for long-term success increases when the cause of river instability is addressed, and the stable geomorphic tendency of the stream is established during the design process.

Using a holistic, multidisciplinary approach to river restoration design, the stream channel, riparian area, floodplains, and wetlands are restored. Data collected from stable streams in the same hydro-physiographic region, also known as reference reaches, are used as a template for design to develop the dimensions, patterns, and profiles for the restoration of an unstable site. Even when an individual streambank is being addressed, this same approach can be used to develop a streambank restoration design. Stable rivers have the capacity and competence to transport their flows and corresponding sediment loads. As part of the design development process, local hydrology and sediment transport are evaluated. This approach is outlined in the USDA-NRCS National Engineering Handbook, Part 654, Chapter 11 (NRCS, 2007). New techniques, such as toe-wood structures, have been added to enhance the resiliency of the channel boundary to prevent scour and dissipate energy. Locally developed strategies for creating floodplains that are resistant to scour, preplanting these features during the construction process to rapidly establish native vegetation to reduce post-construction erosion and establishing projects with long-term resiliency have been introduced in recently completed projects.

Individual streambanks can be restored by combining NCD principles and NRCS land management practices. Also, low-tech beaver dam analogs or post-assisted log structures can be used in low gradient systems to reduce erosion and reconnect floodplains. Lastly, streambank stabilization techniques under the right conditions can be used to stop erosion. Table 4-3 provides a summary of methods and practices used in the Beaver Lake Watershed that have been successful in restoring river reaches and streambanks. Other methods and approaches can be used, but it is beyond the scope of this section of the plan to present these. A general reference for industry-standard stream restoration techniques is presented in

USDA-NRCS National Engineering Handbook, Part 653 – Stream Corridor Restoration: Principles, Processes, and Practices (NRCS, 2001)and Part 654 – Stream Restoration Design (NRCS, 2007).

Table 4-3. Potential Approaches and Practices for Addressing Stream Instability and Streambank Erosion within the Beaver Lake Watershed.

Description	Application	Resources
Holistic approach based on geomorphic conditions		
River restoration using NCD principles that incorporates comprehensive native vegetation establishment	Unstable sections of river and streams that include at least one complete meander wavelength	Geomorphic approach is outlined in USDA-NRCS National Engineering Handbook, Part 654, Ch 11, (NRCS, 2007). Additional components include toe-wood structures and rapid native plant establishment utilizing biodegradable materials and incorporating plants during construction (WCRC, 2015)
Program-based approach where NCD principles are combined with funding programs		
Streambank restoration using NCD principles, NRCS land management practice, and native vegetation establishment	Sections of river and streams that have a single erosive streambank	Same as described above and NRCS Land Management Practices: 410 Grade Stabilization Structures, 580 Streambank and shoreline protection, 490 tree and shrub site prep, 612 tree/shrub establishment,484 mulching, 342 critical area planting; WCRC native plant establishment approach
Streambank stabilization and other practices		
Direct treatment of eroding area	Single erosive streambank; more applicable in urban areas or low-gradient, headwater streams	NRCS Streambank Stabilization Practices and other restoration approaches described in USDA-NRCS National Engineering Handbook, Part 653, (NRCS, 2001) and Part 654 (NRCS, 2007). Low Tech Erosion Control: NRCS Conservation Practice 643

4.2.2.4 Unpaved Road Improvements

Portions of this section were contributed by Sandi Formica and Matthew Van Eps from WCRC.

Roads can be a major source of sediment and associated pollutant loading through both direct and indirect means. Unstable roadside ditches are often a significant source of sediment load. In addition, unpaved roads are a direct source of sediment loading including fine sediment that leads to elevated turbidity in Beaver Lake and its tributary streams. Some of the undesirable consequences of these roads are that they can destabilize the hydrology and geomorphology of the landscape. These roads are a source of accelerated sediment production to streams in which stormwater runoff erodes the surface and ditches, especially where there is steep terrain and increased rainfall. Vehicle traffic fragments roadbed surface materials into smaller and smaller particles. These particles runoff to the surrounding streams, and more readily become entrained in the water column and remain in solution. This impacts not only water quality, but aquatic life and aquatic habitat, clogging fish gills and streambed interstitial spacing that normally provides spawning conditions for fish (Castro & Reckendorf, 1995).

As part of the WFWR watershed-based assessment (DEQ, 2004), the Watershed Erosion Prediction Project (WEPP), specifically, the web-based, “WEPP Roads” model was used to estimate sediment loadings from unpaved roads (Elliot, Hall, & Schelle, 1999). As with many forested watersheds, unpaved roads were constructed to provide access to harvest timber to construct railroads in the 1800s and later for commercial purposes. Today, these roads are traveled to access farms, homes, and recreational areas. The WFWR watershed has approximately 120 miles of unpaved with at least 67% having ditches.

In addition to ditches, the WEPP model considers other factors that influence sedimentation including the roadway design, surface type, level of use, precipitation amounts, and buffer characteristics from the road to stream. For the WFWR evaluation, the WEPP Roads model was utilized for a watershed-based assessment of sediment yield from inventoried roads following a methodology developed by the Ouachita National Forest Service. Data were collected for all public unpaved roads based on road groups and a percentage of road segments was modeled and applied to the inventoried roads (DEQ, 2004). In addition to erosion, WEPP models sediment that enters the stream networks. Erosion coefficients ranged from 3.1 tons/mi/yr to 73.8 tons/mi/yr and export coefficients ranged from 3.1 ton/mi/yr to 55 ton/mi/yr. The average sediment export coefficient from unpaved roads in the WFWR watershed was 35.9 tons/mi/yr. The total sediment load to the stream network was 4,500 tons from unpaved roads with 75% of the total being from unpaved public roads with ditches.

The Alliance requested the WCRC to develop maps showing unpaved roads in the Beaver Lake watershed and highlight areas that would be a priority for implementing conservation practices. Priorities for the WFWR watershed are described by DEQ (2004). Maps showing roads and priorities for conservation practices implementation can be found in Appendix C. Utilizing the average sediment export coefficient from the WFWR study, Table 4-4 presents the miles of unpaved roads in each subwatershed within the Beaver Lake Watershed and an estimate of annual sediment generated from this source.

To assess unpaved roads compared to the other sources modeled within the assessment completed for this Strategy update (Section 2.2), the subset of impervious areas within each catchment that cover unpaved roads was extracted and compared to the remaining loads for each catchment. Figure 4-5 defines the percentage of unpaved roads within developed areas of each NHDPlus catchment.

Table 4-4. Estimate of Sediment Loadings to Streams in Beaver Lake Watershed Subbasins Based on WEPP Modeling in the WFWR Watershed.

Watershed Basin	Miles of Unpaved Roads	Estimate of Sediment Loading (tons/yr)
Beaver Lake/Lakeside	716	25,704*
Richland Creek WS	258	9,804*
Middle Fork WS	133	5,054*
White River/Headwaters	109	4,142*
Lake Sequoyah WS	167	6,346*
War Eagle WS	552	20,976*
West Fork White – WEPP Model Results (Arkansas Department of Environmental Quality, 2004)	120	4,500
Total	**2055**	**76,526**

*Based on WFWR avg. export coefficient of 35.9 ton/mi/yr (DEQ, 2004)

Within the geospatial data used to parameterize the watershed model, unpaved roads were defined by calculating those road segments, identified by the U.S. Census Bureau 2020 tiger/line shapefiles, that overlapped with an ICLUS imperviousness of less than 5%. An average road width of 22 feet was then assumed to calculate the area. This method of identifying unpaved roads was then verified using satellite imagery. To define those areas that were considered "developed," we applied two methods: (1) land areas identified as having an NLCD land cover that is developed (NLCD 21, 22, 23, 24), and (2) land areas identified as having an NLCD land cover of Forest (NLCD 41, 42, 43) but an ICLUS land use that is medium-high developed (ICLUS 12-18). The proportion of unpaved road area to developed area (identified by NLCD) was then calculated for each catchment. Consequently, the colored lines in Figure 4-5 show unpaved roads are present in the developed areas of the watershed, whereas the white lines show a developed area with no unpaved roads present. The lines in orange and red represent the highest priority for road improvements. In the more rural areas of the watershed, the only developed areas present are the roadways themselves, which explains why up to 85% of the developed land within these NHDPlus catchments is unpaved roads. Figure 4-6 compares the unpaved roads as defined by the percent imperviousness method described above with the unpaved and county roads mapped by AHTD for validation. The AHTD roads map is a selection from the "Roads All" layer sourced from the Arkansas GIS Office, published in 2006 and last updated in 2014. Some of the differences in the two layers are likely attributed to the road improvements since the AHTD layer was last updated.

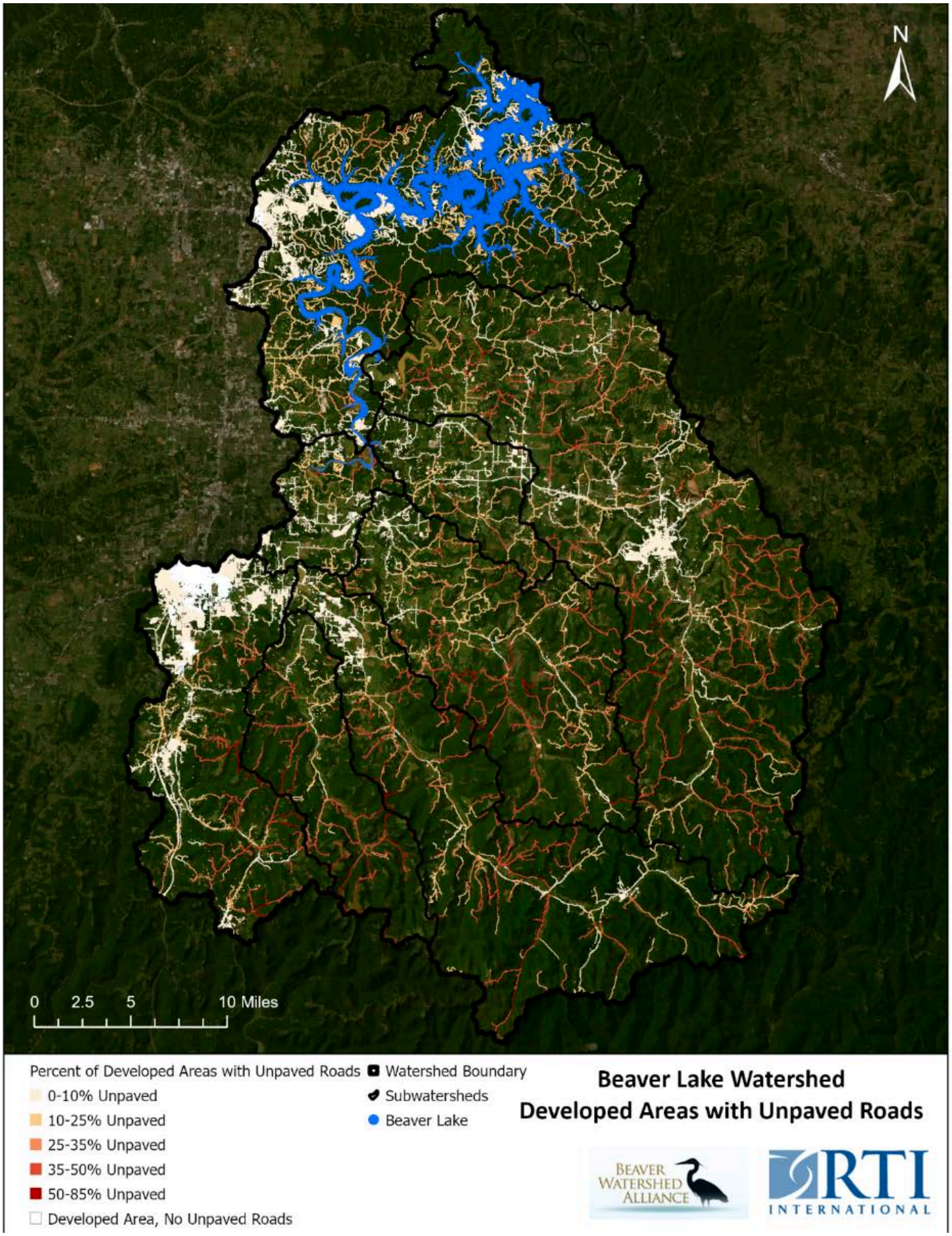


Figure 4-5. Potential Unpaved Road Improvement Priorities within the Beaver Lake Watershed.

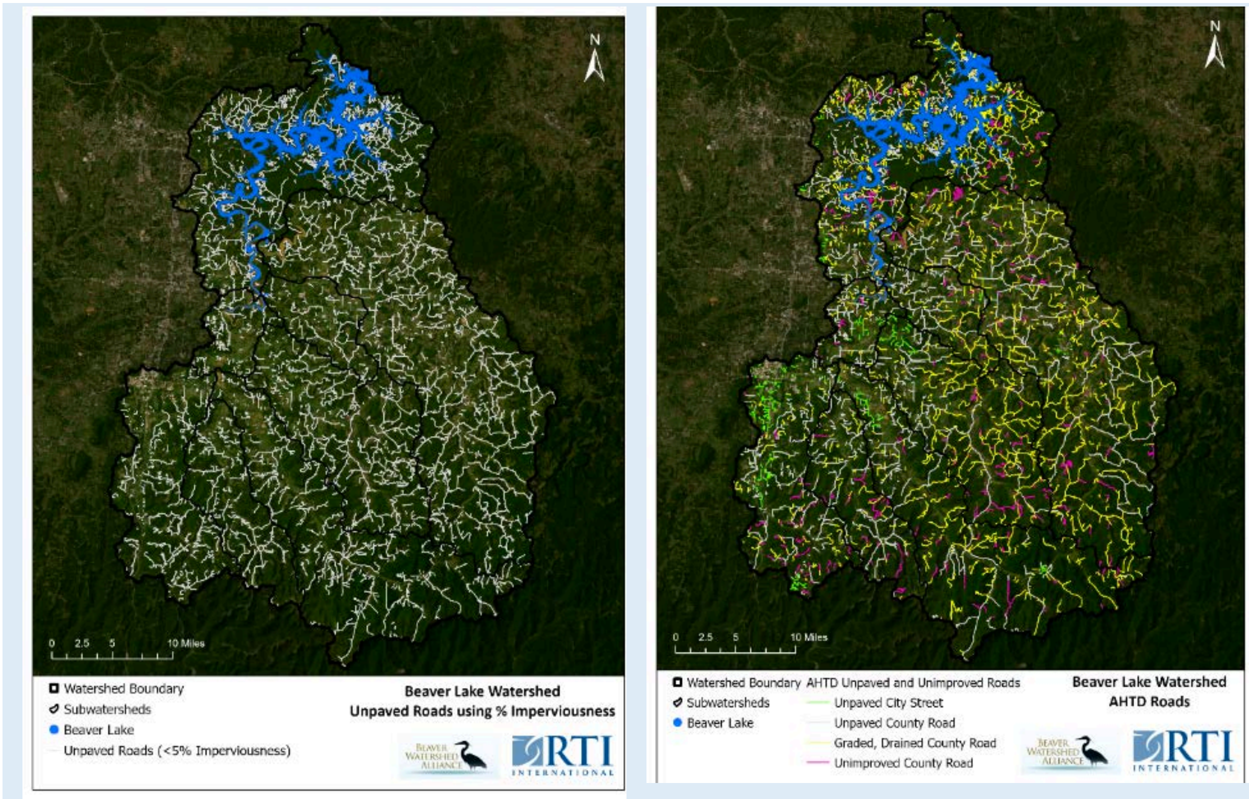


Figure 4-6. Comparison of Percent Impervious Method Used with the AHTD Roads Layer within Beaver Lake Watershed.

By identifying the proportion of developed land within each catchment that reflects unpaved roads, the sediment and nutrient loads derived from this source can be estimated assuming that loads generated are consistent across the unpaved roadways and other developed lands within each catchment. However, due to the resolution of the land cover dataset (98 feet x 98 feet, or 30 meters x 30 meters), the developed grid cells representing unpaved roadways overestimate the road surface width, which is assumed to be 22 feet or 6.7 meters. The model simulates these areas according to the developed land use category assigned via the land cover/land use (NLCD-ICLUS) dataset, which ranges from developed open to developed high density. These categories are simulated with an exponential build up based on a loading rate of mass per area, where these rates were calibrated with an eye towards the actual developed areas, such as in the West Fork White River rather than the build-up rates on unpaved roadways (e.g., 3.1 tons/mi/yr to 73.8 tons/mi/yr as used in the WEPP model). As the individual components of unpaved roadways (e.g., ditches, level of use) are not simulated, this method is used only to assess the relative order of magnitude and geographic distribution of loadings from unpaved roads.

Six example catchments are used to quantify the potential contributions (Figure 4-7 and Table 4-5) from unpaved roadways as compared to other sources in each catchment. These catchments were selected to represent a range of surface and subsurface conditions. The length of unpaved roads across these catchments ranges from 1.5 to 12.2 miles. The sediment load derived from unpaved roads varies across these sites. While the loadings do not show unpaved roads to be a dominant source in any of these locations, the biggest contribution is seen in a forest-dominated catchment in War Eagle Creek. The normalized rate of generation of sediment modeled ranges for 0.3 to 58.4 U.S. tons of sediment generated per mile of unpaved road based on generation rates of 6.0 to 326 tons per example catchment; however, the gross generation is influenced by catchment size.

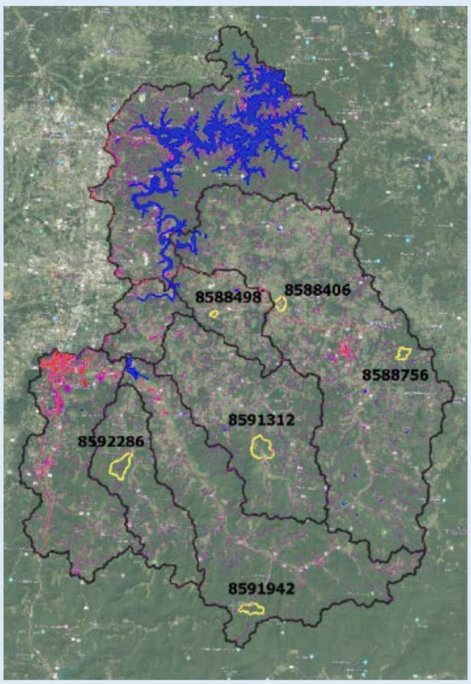


Figure 4-7. Selected Catchments with Unpaved Roads in Beaver Lake Watershed

Table 4-5. Estimated Mean Annual Sediment Load for Selected Catchments with Unpaved Roads in the Beaver Lake Watershed.

NHDPlus COMID (Major land use)	Unpaved Road Load (US tons)	Percent of Surface Load	Length of Unpaved Roads (mi)	Normalized Rate (US tons/mi)
8588406 (84% Ag)	12.1	0.8%	5.5	2.2
8588498 (53% Ag/ 37% For)	21.6	9.9%	1.5	14.7
8588756 (77% For)	326	17%	5.6	58.4
8591312 (63% For/ 33% Ag)	76.8	2.1%	10.6	7.3
8592286 (85% For)	6.0	1.6%	12.2	0.5
8591942 (96% For)	41.2	28%	5.1	8.1

NOTE: "Ag" defines percent pastureland, and "For" defines percent forested land use within the NHDPlus catchments.

To reduce the loadings from this source, the Strategy recommends several types of improvements to unpaved roads that are practical to implement. These include wing ditches and turnouts that direct runoff from the road into undisturbed (vegetated) areas, hydroseeding ditches, and stabilizing stream crossings. Culverts should also be installed at regular intervals to pass drainage from adjacent land underneath roads and reduce stormwater flow passing across road surfaces.

Once a watershed's unpaved roads have been modeled, the WEPP Roads model can be used to locate management practices, such as wing ditches and turnouts, to reduce sediment loadings. Expected sediment load reduction if management practices are applied is 30%. Unpaved road inventories and WEPP Roads model could be applied to the subbasins in the Beaver Lake watershed.

Low water stream crossings and culverts are common along unpaved roads and can prevent fish passage. In addition to estimating sediment delivery to streams, management practices could be planned for priority areas and fish passage barriers would be located as part of the inventory. For example, the WFWR 2004 watershed assessment includes a map with the locations of low water crossings and culverts and subsequent drops (DEQ, 2004).

4.2.2.5 Improved Construction Site Management

A key aspect of the Beaver Lake Watershed Protection Strategy will be to address the runoff of sediment and other pollutants from active construction sites as development continues in the lake's watershed. In the built-out areas regulated under the DEQ's Stormwater Permit Program, cities and counties with MS4s are responsible for overseeing construction sites and implementing measures to reduce runoff and water quality degradation to the maximum extent practicable. This responsibility, which is a requirement of their state MS4 Stormwater Permit, will help to address construction site runoff in the MS4 communities in the watershed.

As discussed in Section 3.1.1, construction sites with a disturbed area of one acre or more that are not in the DEQ MS4 permit areas are still subject to regulation under the NPDES program for construction sites. Under the approach described in this Strategy, cities and counties in the Beaver Lake Watershed should enhance their construction oversight programs throughout the areas that drain into Beaver Lake to protect long-term drinking water quality and aquatic life. Cities and counties should adopt a consistent set of enhanced measures in their jurisdictions and directly enforce them in their MS4 permit areas. At the option of the local governments, polluting construction sites not in the MS4 area may be subject to city or county enforcement or referred to DEQ in the event of violations of construction site permit rules. DEQ has been advised of this approach and has noted that construction site operators have several responsibilities regarding their operations. The following text from the DEQ statewide permit for construction sites was provided by DEQ in response to questions about enforcement of erosion, sediment, and stormwater requirements:

> *"Responsibilities of the Operator. Permittees with operational control are responsible for compliance with all applicable terms and conditions of this permit as it relates to their activities on the construction site, including protection of endangered species and implementation of BMPs and other controls required by the SWPPP. Receipt of this general permit does not relieve any operator of the responsibility to comply with any other applicable federal, state, or local statute, ordinance, or regulation."*

DEQ also confirmed that local ordinances may go beyond the state's minimum requirements pursuant to protection of Beaver Lake and local stream conditions. This Strategy recommends implementing a program that goes beyond the minimum state standards in two ways. This recommendation remains unchanged from the 2012 strategy:

(1) First, the Strategy recommends that all local governments in the watershed have a local enforcement program, to the extent feasible, even in the non-urbanized area where there is currently state jurisdiction. It is assumed that local governments are enforcing their current regulations to the greatest extent possible, but (some) are not in compliance with the NPDES requirements. It is important to note that enforcement has been an issue for some municipalities, citing a lack of resources and manpower. Where local governments outside the MS4 area cannot take on enforcement, it is recommended that problem sites be identified and referred to DEQ for follow-up and possible enforcement. A voluntary construction site monitoring program could help support local governments in this effort.

(2) Second, the Strategy recommends more protective controls than those found in the minimum state requirements. The recommended controls include silt fencing with other controls and sediment basins for all sites that will disturb five acres or more during the construction period, with project phasing and rapid stabilization of bare areas at final grade (i.e., no more than 33% of the site is bare at any time and stabilization within 10 days of reaching final grade). Disturbed areas inactive for 14 days would also be stabilized with mulch until grading resumes.

4.2.2.6 Pasture Management

Cattle manure can be a source of nutrient and bacteria loading to streams, particularly where direct cattle access is not restricted and/or where cattle feeding structures are adjacent to riparian areas. Direct deposition of feces into streams by cattle is a primary mechanism of pollutant loading during baseflow periods. During storm events, overbank and overland flow may entrain manure accumulated in riparian areas, resulting in pulsed loads of nutrients and other pollutants. In addition, cattle with unrestricted stream access typically cause severe streambank erosion. Recommended pasture conservation practices involve excluding cattle from streams using fencing, providing an alternative water source, and providing stream crossings where necessary.

Rotational grazing involves the frequent movement of livestock through a series of pasture subdivisions called paddocks. This frequent movement allows plants to rest and regrow to grazing height while livestock graze other paddocks. The length of grazing and rest periods is ecosystem dependent and differs depending on forage yield, stocking density, and season. Each paddock must contain forage, water, and adequate shade. Rotational grazing has been implemented with livestock including cattle, sheep, goats, and horses.

Pasture renovation can also be a cost-effective strategy to reduce nutrient and sediment loading from pastures. A pasture renovator is equipment that uses large spikes (found in various shapes and sizes) to create many small indentations in the ground that hold water and nutrients. Pasture areas along slopes leading to surface waters and pasture streamside zones are high priority areas for treatment by the renovator. This practice produces multiple benefits to forage growth and water quality. A study, "Economic and GHG emissions of Aeration and Gypsum Application" (Popp, et al., 2021), was conducted in the Beaver Lake watershed with the University of Arkansas and USDA NRCS. The publication, including a local survey, "Profitability Assessment for Nutrient Runoff Mitigation Practices on Hay Fields and Pastures" (Popp, et al., 2021) provides guidelines and recommendations for pasture aeration in the Northwest Arkansas region. Pasture aeration (aeration and sub-surfer) decreased nitrogen and phosphorous loads by 49% and 37%, respectively, while increasing forage yield by up to 30%. Infiltration results are somewhat mixed, but generally June aeration increased infiltration the most relative to the control. Results of the survey included:

- 80% of respondents were engaged in cow-calf production
- 70% of respondents reported haying and grazing activity
- 10% of respondents also involved with poultry production
- 67% reported aerating in early spring before the spring growth surge

Respondents were asked to describe their willingness to pay per acre to use an aerator if the result of aeration was a reduction in nutrient runoff by 10% and increased forage production by 5%.

- 33% percent respondents stated they would be willing to pay $0.01 to $0.99/acre to aerate
- 11% would be willing to pay $1.00 to $2.49/acre to aerate
- 44% said they would be willing to pay nothing to aerate their fields
- 22% stated they would require a subsidy payment to cover their tractor operating costs for aeration
- 44% of respondents stated they have considered purchasing an aerator
- 56% stated they have not considered purchasing an aerator

To identify those pasture areas in the watershed that could have the greatest benefit from pasture renovation, a GIS analysis of riparian pasture parcels was performed, as described in Section 4.2.2.2. Those priorities also apply to pasture management.

4.2.2.7 Agricultural Ponds

As highlighted by the study "Simulated Use of First Order Ponds to Reduce Peakflow in an Eroding River System" (Scott & Haggard, 2015), agricultural ponds that already exist on pastureland prove to be the most economical (and consequently realistic) option for retrofitting into a stormwater pond. To identify current locations of agricultural ponds, hence highlighting priority areas for stormwater pond retrofitting, a GIS analysis was performed. These agricultural ponds were identified using the “water” land cover type (NLCD 11) for the watershed to select out “water areas”. This process was then verified using satellite imagery and proved to accurately capture ponds, except for ponds less than 1 acre. Then, those “water areas” that were within a 32.8 feet (10-meter) buffer of property parcels with the majority land cover as pasture were selected, so as to select out water areas that are within pastureland. To ensure that those water areas selected are indeed ponds and not streams or large lakes, those “water areas” that were within a 30-meter (98.4-ft) buffer of the NHDPlus streamlines or the Beaver Lake were removed from the selection. This resulted in estimated “agricultural ponds” based on the NLCD 2016 Ponds. Further aligning with Scott & Haggard (2015), the headwater catchment risk for the Beaver Lake Watershed NHDPlus catchments was calculated based on the curve numbers used in WaterFALL modeling efforts, and the methods described by Scott & Haggard (2015). The curve numbers were assigned based on the unique combination of land cover (NLCD) and land use (ICLUS) layers for each zone with a common catchment, land cover, and land use. The mean curve number was then calculated for each NHDPlus catchment.

These headwater catchment basins were then categorized into the following groups:

- All headwater subbasins, defined as having low hydrologic risk
- Headwater subbasins with moderate hydrologic risk (Curve Number 70-74)
- Headwater subbasins with elevated hydrologic risk (Curve Number 75-79)
- Headwater subbasins with severe hydrologic risk (Curve Number 80 or higher)

Figure 4-8 represents the headwater catchment risk throughout the watershed, overlaid with the count of agricultural ponds per headwater catchment, as defined by the outlined catchments. Only those headwater catchments with more than one pond are labeled. The intersection of high headwater catchment risk and a high count of agricultural ponds represents the greatest opportunity for stormwater pond retrofit. It is important to note these maps represent priorities based on the baseline curve numbers for each catchment (as opposed to future curve numbers). This analysis could be performed in a future study (RTI International, 2022).

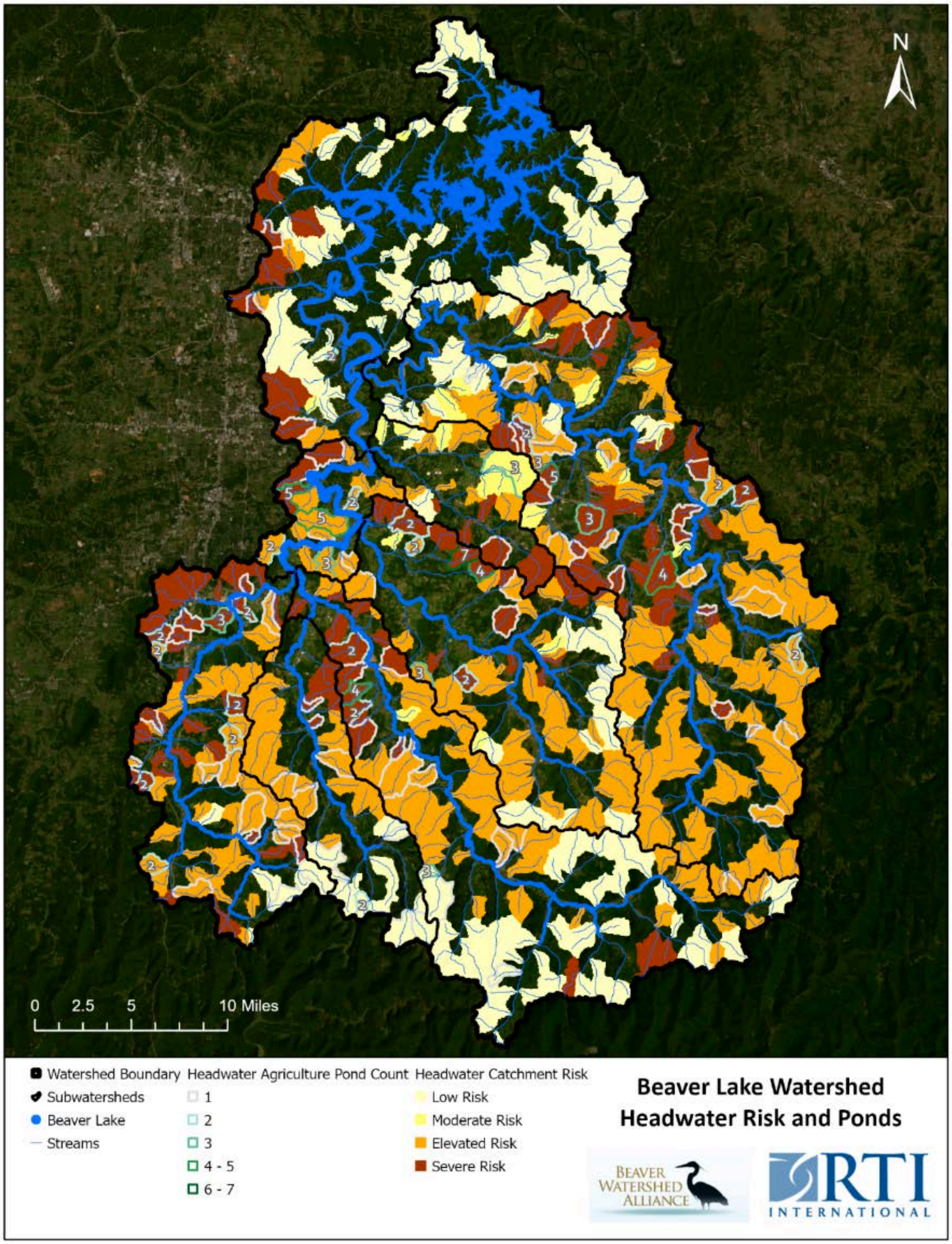


Figure 4-8. Headwater Catchment Risk and Estimated Headwater Agricultural Ponds across the Beaver Lake Watershed.

4.2.2.8 Manure Management for Animal Operations

Beaver Lake Watershed has a large agricultural presence, amounting to approximately 20% of the watershed area according to ICLUS 2020 pasture and grazing land uses. Most of these farms have confined poultry and or cattle-calf operations that result in potential significant nutrient loadings due to manure application. Nutrients play an essential role in these practices, nutrients are necessary for both the feeding of animals, and growing of food. They are also a byproduct of cattle and poultry farming in the form of manure. Manure can be a very valuable resource to both farmers and the watershed when applied correctly, as it can introduce nutrients and organic material to the rocky soils. However, if not managed appropriately, manure and chemical fertilizers can runoff into waterways and negatively impact water quality (Environmental Preservation Division, 2004).

The impacts of manure application were integrated into the WaterFALL watershed model referenced in this Strategy. For more details on how poultry houses were identified and how manure loads were incorporated into the watershed model, see Section 2.2.1.1.

To improve manure management in the region, development of nutrient management plans is needed, as outlined in *Act 1061: An Act to Require Proper Application of Nutrients and Utilization of Poultry Litter in Nutrient Surplus Areas* and supporting legislation described in Section 3.4. In addition to nutrient management plans, various BMPs (Rieck-Hinz & Andersen, 2012) can be implemented, including:

- Installing an anaerobic digester to use manure to produce biogas, that can in turn be burned to generate electricity; this can minimize greenhouse gas emissions from manure storage (USDA Economic Research Service, 2020).
- Awareness of soil conditions and weather forecasts before land application, as high rainfall intensity can result in loss of nutrients to runoff and soil erosion.
- Application of manure away from water sources and properly spaced from sinkholes, wells, designated wetlands, other manure application sites.
- Frequent manure removal from buildings, storage covers, or manure injection.
- Calibration of manure application equipment to ensure an appropriate application rate and improve efficiency.
- Development of an emergency manure spill response plan.

4.2.2.9 Improved Stormwater Management and LID

Stormwater conservation practices include retrofitting existing stormwater ponds to improve pollutant removal and providing additional volume and peak control. Retrofit projects would involve the targeted construction of new stormwater facilities to treat and control runoff from existing development. New stormwater facilities may include wet detention, dry detention, stormwater wetlands, bioretention, or other similar facilities.

Low impact development (LID) and green infrastructure (GI) are also important components of improving stormwater management. According to the U.S. EPA, LID encompasses “systems and practices that use or mimic natural processes that result in infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat,” utilizing stormwater as a resource rather than treating stormwater as a waste product. GI refers to the “management of wet weather flows” that use these LID practices. Some examples of these practices include bioretention facilities, bioswales, rain gardens, green roofs, permeable pavement, and rain harvesting. These practices not only minimize the effects of urbanized areas on water’s natural flow through a watershed, improving water quality and reducing flood impacts, but they preserve or create green spaces, improving street and park landscapes, air quality, and property value. When applied on a larger scale, LID has the potential to “maintain or restore a watershed's hydrologic and ecological functions” (U.S EPA, 2022).

To identify priority areas for implementation of these practices, urbanized catchments were first isolated. This was done by finding those catchments with significant areas of NLCD Land Cover Type 23 (Developed, Medium intensity), shown in medium red, and Type 24 (Developed, High intensity), shown in dark red in Figure 4-9. Then, those areas with the highest amounts of current and future runoff were identified in Figure 4-10. The areas in greens and yellows are deemed the highest priority.

Drainage areas in these impaired watersheds with high baseline and future runoff values should be prioritized for conservation practice retrofits, and LID should be considered, especially if these drainage areas lack stormwater treatment and control facilities.

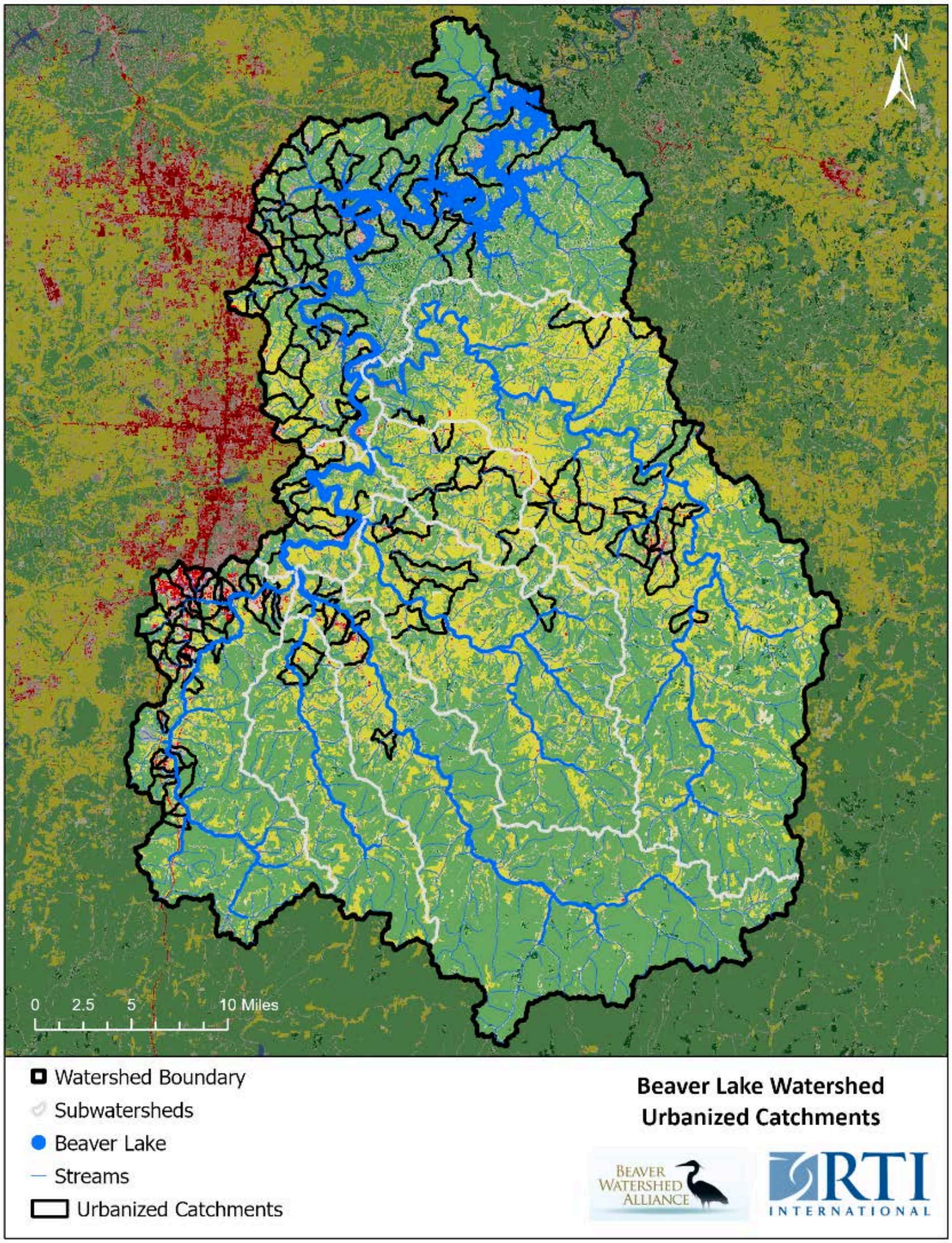


Figure 4-9. Urbanized NLDPlus Catchments Identified within the Beaver Lake Watershed. Map Based on Significant Areas of NLCD Type 23 (Developed, medium) and 24 (Developed, high), Overlayed with the NLCD Base Layer (see Figure 2-5 for the full legend).

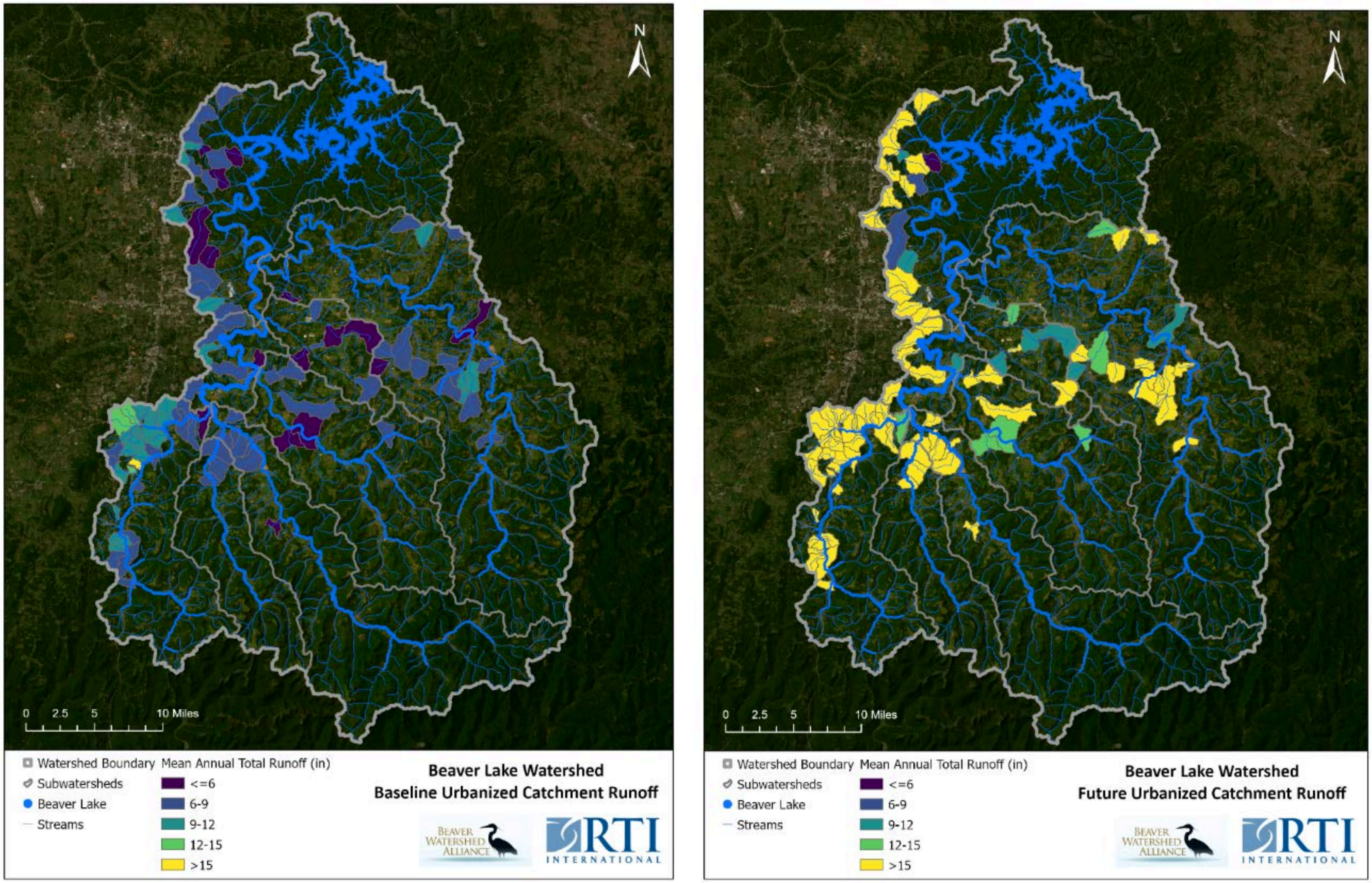


Figure 4-10. Baseline (left) and Future (right) Stormwater Priority Areas for the Beaver Lake Watershed, where Yellow and Green NLDPlus Catchment are the Suggested Highest Priorities.

4.2.3 Component #3 – Education and Outreach

The purpose of an education and outreach program is to bring about behavioral changes and encourage conservation practice implementation that will lead to reduced sediment and pollutant transfer in the watershed. Programs should educate the public about the causes of pollution and provide stakeholders with tools they can use to support and promote watershed conservation, restoration, and protection.

Educational and stewardship programs should aim to reach a variety of stakeholders. The success of watershed community efforts depends on cooperative partnerships built on understanding, trust, and respect. Because they reflect the community's needs, on-the-ground projects encompass a wide variety of natural resource issues, especially a strong education and outreach component. The Beaver Watershed Alliance has established core educational programming broadly based on land use and addresses sediment and nutrient reductions. Programming includes education and outreach for farmlands/agricultural landowners, forest landowners, urban landowners, streamside landowners, and pasture/grassland landowners. Stewardship programming includes mainly urban and streamside projects, including invasive plant removals, tree and shrub establishment, and native planting, conducted with volunteers on both private and public lands.

4.2.3.9 Target Audience

There is a wide target audience for this education and outreach program to maximize the potential behavior changes brought about by the recommended activities. Different types of activities, topics, and presentation styles are provided considering the following groups: public, riparian landowners, homeowners/property owners, school children, “active” citizens, the agricultural community, municipal employees, construction managers, designers, and business owners.

Education programs targeting homeowners should concentrate on information, skills, and demonstrations of specific practices. Written materials are the most common source of water quality information for local officials. In contrast to watershed residents, two-thirds of local officials seek water quality information through meetings. Education efforts for local officials should continue to help communities understand and assess water quality provisions within their own plans and ordinances. Water quality education efforts for local officials should facilitate communication and coordination of water quality between neighboring communities.

Education and outreach tailored toward contractors and developers is needed at the local government level or city council, planning, and engineering departments to increase awareness on water quality and management issues in the watershed, as well as available solutions to address them.

4.2.3.10 Key Messages

The overall message of the Beaver Lake Watershed Protection Strategy Education and Outreach Program is:

"Efforts you make can help restore and protect the Beaver Lake watershed so that everyone can enjoy the benefits provided by clean and safe streams, rivers, and lakes."

This message is intended to be general, apply to a wide audience, and be understood by younger people. Other more specific, targeted messages are suggested as follows for the topic areas addressed in the program:

- **Septic Systems:** "Get to Know Your Septic System," programming developed by H2Ozarks. (Note: Figure 2-16 shows the locations within the watershed with the estimated greatest concentration of septic tanks as tallied from available data on rural buildings and sewered areas within the watershed.)
- **Poultry Houses:** "Managing Phosphorus for Agriculture and the Environment." Phosphorus is an essential element for plant and animal growth and is necessary to maintain profitable crop and livestock production. Learn how to manage your nutrients for maximum returns. (Note: Figure 2-17 shows the locations of poultry houses within the watershed based on a GIS analysis performed.)
- **Agricultural Practices:** "Pasture and Profitability," or "Grow Your Farm and Help the Environment Too," "Soil and Water Strategies to Grow Your Farm," and "Growing Conservation."
- **Residential Practices:** "Only Rain Down the Drain" or "Know the Flow" programming developed by University of Arkansas Division of Agriculture, Extension Services.
- **Erosion and Stream Stabilization:** "Land Loss and How You Can Do Something About It," Eroding Away – Save Your Lands from Storms," and "Streambank Restoration 101 – Permitting and Repairs."
- **Construction Practices:** "During Construction Build It Right – Keep Soils on Site," programing by UA Division of Agriculture, Cooperative Extension Services.

4.2.3.11 Existing Programs to Leverage

Because so many activities have taken place within the region and around the country, the examples described in this section are worth noting for reference. Municipalities have several ongoing events and programs at which information can be made available to interested stakeholders or broadcast as part of a larger program. These events may also be used to inform stakeholders of, and register participants for, planned workshops or to conduct the baseline and future follow-up surveys for assessing stakeholder knowledge and behaviors related to the watershed.

In addition to ongoing programs, there are also specific annual activities pertinent to the watershed that could be used to distribute information, recruit volunteers, or enroll stakeholders in workshops, field days, or other activities:

- **Secchi Day on Beaver Lake:** Beaver Water District's Secchi Day is an annual event that takes place on Beaver Lake with the goal of citizen scientists collecting important water quality data such as turbidity, chlorophyll *a*, total phosphorus, and total nitrogen. Secchi sampling typically happens in August, with a celebration event in October.
- **West Fork – White River Cleanup:** Annual cleanup that started around 2006 and continues today. Landowners, local conservation groups, water utilities, cities, and volunteers engage in cleaning up the streams and riparian areas around the West Fork watershed area. The event usually concludes with a celebration and raffle. The event typically occurs in spring or fall.
- **War Eagle Appreciation Day:** Annual event that started around 2004 and continues today. Landowners, local conservation groups, water utilities, Withrow Springs State Park, Hobbs State Park, AR Dept of Tourism, cities, and volunteers engage in cleaning up War Eagle Creek and hosting a water-related festival at Withrow Springs State Park. The event typically happens on the first Saturday in June.
- **Arkansas Water Resources Conference:** Annual event with research, science, and presentations of water-related topics in the NWA region. This event typically occurs in July.
- **Beaver Watershed Alliance Friendraiser:** Annual event for landowners and conservation groups to engage and network with each other. This event is typically held in the fall.

4.2.4 Component #4 – Monitoring and Adaptive Management

The management actions needed to reduce sediment loading in the Beaver Lake watershed will take time, will be expensive, and will require active participation from many different people, organizations, agencies, and policymakers. The previous and updated Beaver Lake Watershed Protection Strategy was developed based on historical monitoring data for the watershed and lake, projections of future development through the year 2050, and modeling that predicted the watershed processes and lake responses to that new development. There is uncertainty in all long-range growth projections and in modeling, and conditions change: new water quality protection technologies will emerge, climate conditions may change, and lake water quality may improve or decline. Historical and ongoing monitoring efforts provide critical information for characterizing the current stressors and impacts within the Beaver Lake watershed. However, additional monitoring and assessment efforts are needed to protect Beaver Lake's water supply and recreation in the coming decades.

It is important that a long-term monitoring program exists to provide a technical foundation for an adaptive management process. As a part of the iterative adaptive management approach, several types of additional monitoring are recommended to serve as early warning indicators:

- Water quality monitoring,
- Monitoring of conservation practices, and
- Monitoring and tracking of outreach and education programs.

As of 2020, there are 52 water quality monitoring stations collecting water quality data throughout the watershed (Table 4-6); however, many of these stations overlap between various organizations, so these are not 52 unique water quality monitoring stations. While these stations do not all monitor every parameter necessary to detect changes in water quality with program implementation, the list collectively represents a level of monitoring that may be helpful in evaluating program and conservation practices' impact. Specifically, the stations included in this list collect parameters including total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), specific conductivity (SC), total dissolved solids (TDS) and, in the case of USGS, limited data on suspended solid concentration (SSC). However, not all years are consistent in frequency and not all stations collect all parameters. It is of note that there is a lack of frequent and widespread data collection related to

- Streambank erosion,
- Storm events, and
- Headwater locations with corresponding streamflow monitoring to allow for calculation of loadings.

These data are important to collect for incorporation into future monitoring and modeling efforts.

Table 4-6. Historic and Current (circa 2022) Water Quality Monitoring Stations within the Beaver Lake Watershed.

Count	Agency	StationID	Description	Latitude	Longitude	Monitoring Frequency
1	ADEQ	WHI0052	White River on SR45/W Bowen Rd near Goshen	36.105999	-94.011398	6 times/yr

Count	Agency	StationID	Description	Latitude	Longitude	Monitoring Frequency
2	ADEQ	WHI0070	Holman Creek on SR23 BL Huntsville	36.124802	-93.733902	6 times/yr
3	ADEQ	WHI0100	W Fork White River on CR55/Dead Horse Mountain Rd	36.050598	-94.118896	6 times/yr
4	ADEQ	WHI0103	Middle Fork White River on CR51/S Harris Dr SW of Elkins	36.014	-94.067001	6 times/yr
5	ADEQ	WHI0106	White River off SR16 on CR183 at Durham	35.956001	-93.978996	6 times/yr
6	ADEQ	WHI0116	War Eagle Creek at SR45 N of Hindsville	36.201698	-93.856903	6 times/yr
7	ADEQ	WHI0207	War Eagle Cave Spring at War Eagle Cave at Withrow Springs S	36.150002	-93.739998	6 times/yr
8	ADEQ	WHI0209	Withrow Spring at Withrow Springs Cave at Withrow Springs St	36.150002	-93.730003	6 times/yr
9	AWRC	WEC	War Eagle Creek near Hindsville, AR	36.2	-93.855	30+ times/yr
10	AWRC	Wyman	White River near Fayetteville, AR, at Wyman Road	36.07305556	-94.08111111	30+ times/yr
11	AWRC	WFWR	West Fork of the White River East of Fayetteville	36.05388889	-94.08305556	30+ times/yr

Count	Agency	StationID	Description	Latitude	Longitude	Monitoring Frequency
12	AWRC	WR Elkins	White River Near Elkins, AR	36.00083333	-94.00361111	30+ times/yr
13	AWRC	Richland	Richland Creek Tuttle Road near Goshen	36.04861111	-93.97416667	30+ times/yr
14	AWRC	TB	Town Branch at Armstrong in Fayetteville	36.04333333	-94.13611111	30+ times/yr
15	District	10	WR at Wyman	36.073043	-94.080958	Monthly
16	District	5	WR at Elkins	36.000826	-94.003845	Monthly
17	District	9	WE at War Eagle Mill	36.267536	-93.943389	Monthly
18	District	15	WE at Old Hwy 412	36.121538	-93.694115	Monthly
19	District	21	War Eagle Creek at Hwy 23 Bridge	36.149926	-93.740481	Monthly
20	District	12	Tributary below Parson's Landfill	36.174753	-94.046299	Monthly
21	District	7	MFWR at Co Rd 51	35.995816	-94.072721	Monthly
22	District	13	WR at Bank's Farm	36.087654	-94.070504	Monthly
23	District	8	WFWR at Stone Bridge	36.050659	-94.118764	Monthly
24	District	22	Lake Sequoyah	36.066783	-94.07035	Monthly
25	H2Ozarks	101	West Fork at Baptist Ford Bridge	35.982714	-94.173129	1-4 times/yr
26	H2Ozarks	102	West Fork (Brentwood Park) 3	35.865723	-94.117257	1-4 times/yr
27	H2Ozarks	103	Baldwin Creek Near St. Paul	35.822256	-93.758937	1-4 times/yr
28	H2Ozarks	104	White River Near St. Paul	35.819376	-93.781475	1-4 times/yr
29	H2Ozarks	107	War Eagle Creek - Upstream Huntsville	36.041958	-93.703225	1-4 times/yr
30	H2Ozarks	200	Ward Slough	35.997178	-94.173949	1-4 times/yr

Count	Agency	StationID	Description	Latitude	Longitude	Monitoring Frequency
31	H2Ozarks	201	Middle Fork of W.R. at Harris Rd	35.99622	-94.073197	1-4 times/yr
32	H2Ozarks	202	Mullins Creek at the U of A	36.059103	-94.178209	1-4 times/yr
33	H2Ozarks	205	Hock Creek	36.022364	-93.859988	1-4 times/yr
34	H2Ozarks	206	Spout Spring Branch	36.055019	-94.161107	1-4 times/yr
35	H2Ozarks	210	Town Branch (White River Ball fields)	36.042974	-94.135464	1-4 times/yr
36	H2Ozarks	300	Brush Creek	36.131947	-93.947956	1-4 times/yr
37	H2Ozarks	301	War Eagle Creek (Huntsville)	36.149997	-93.740137	1-4 times/yr
38	H2Ozarks	302	Glade Creek	36.159851	-93.81169	1-4 times/yr
39	H2Ozarks	303	Clear Creek	36.195153	-93.789276	1-4 times/yr
40	H2Ozarks	304	Clifty Creek	36.239525	-93.907125	1-4 times/yr
41	H2Ozarks	305	War Eagle (Mill)	36.267597	-93.94313	1-4 times/yr
42	H2Ozarks	306	Prairie Creek	36.341208	-94.096513	1-4 times/yr
43	H2Ozarks	307	Holman Creek Upstream of Huntsville	36.104418	-93.75675	1-4 times/yr
44	H2Ozarks	308	Holman Creek Downstream of Huntsville	36.124453	-93.734211	1-4 times/yr
45	USGS	07048495	*Town Branch at Armstrong St. at Fayetteville, AR	36.0432583	-94.1360222	6 times/yr
46	USGS	07048550	West Fork White River east of Fayetteville, AR	36.05388889	-94.0830556	6 times/yr
47	USGS	07048600	White River near Fayetteville, AR	36.07305556	-94.0811111	6 times/yr
48	USGS	07048700	White River near Goshen, AR	36.1058333	-94.0111111	6 times/yr

Count	Agency	StationID	Description	Latitude	Longitude	Monitoring Frequency
49	USGS	07048780	Richland Creek near Goshen, AR	36.04855556	-93.9742222	6 times/yr
50	USGS	07049000	War Eagle Creek near Hindsville, AR	36.2	-93.855	6 times/yr
51	USGS	07049050	War Eagle Creek at War Eagle, AR	36.26757447	-93.9432535	6 times/yr
52	USGS	07049160	War Eagle Creek above White River nr Lowell	36.22319444	-94.0104444	6 times/yr

NOTE: Several of the water quality monitoring stations overlap between organizations, and *Town Branch was moved to Morningside Drive in 2023.

ENVIRONMENTAL GOALS

The overarching goal of this watershed protection strategy would be that all waterbodies meet or exceed applicable water quality standards, and this strategy would set expected load reductions needed to achieve these goals and protect water quality at Beaver Lake. However, load reductions at the watershed scale are a challenge to achieve because climate (e.g., rainfall intensity, duration, and depth) and hydrology (e.g., rainfall-runoff response) often drive the magnitude, frequency and total amount of nutrient and sediment loads. Therefore, this watershed protection strategy is going to use directional change in water quality to evaluate success and the need for adaptive management.

This strategy will use the directional change in water quality (e.g., Figures 1-2, 1-3, and 1-4) as the metric needed to meet environmental goals, i.e. protecting water quality at Beaver Lake. The idea will be to continue water-quality monitoring at sites with long-term data available (e.g., Grantz and Haggard, 2023), and then use these data to understand how water quality is changing over time in the major inflows into Beaver Lake. The desired directional changes or water-quality targets will vary across the major inflows and other sites within the watershed (e.g., West Fork White River), based on the historical trends at each site. These desired directional changes are detailed below:

White River Watershed

The current water-quality trajectories show decreasing nutrient concentrations over time at the White River at Wyman Road Bridge (Wyman, USGS Site 07048600, Figure 1-2), but no relative change in sediment concentrations at this site.

The environmental goals for this monitoring site would be to see continued reduction in nutrients, or even potentially maintaining flow-normalized nutrient concentrations over time at the current levels; sediments need to show reductions over time.

Within this larger watershed, there are potentially two other sites where trajectories in water quality could also be assessed; these include (1) West Fork White River (WFWR, USGS Site 07048550) and the White River near Elkins (WR-Elkins, USGS Site 07047980). The WFWR site has data going back to 2009, where samples have been consistently collected and analyzed by the AWRC (Grantz and Haggard, 2023). From these WFWR data, we see directional changes not too different than that further downstream at the White River (i.e, Wyman), and these can be summarized as (Figure 4-11):

- Flow-normalized TN concentrations show a strong seasonal pattern and a decreasing pattern through 2022, but TN may have leveled off in recent years (2018–2022).
- Flow-normalized TP concentrations show a seasonal signature, no change in the mean and range in the first few years (2009–2013), and a decreasing TP pattern since 2014 (through 2022); however, TP may have leveled off recently (2018-2022).
- Flow-normalized TSS concentrations show a seasonal signature and relatively little change over time from 2009 through 2022.

The site of the White River near Elkins (WR-Elkins) has just recently started building a water-quality database, so eventually directional change in water quality at this site will need to be assessed. The environmental goal above applies to all sites (i.e., site trends) within the White River Watershed.

Richland Creek

The Richland Creek watershed presents an interesting challenge regarding setting goals of directional change in water quality, because we see divergent changes in water quality at the current site (Richland, USGS 07048780) and the further downstream site (RC45, USGS 07048800). ***The environmental goals for this watershed would be to see continued reduction in nutrients, or even potentially maintaining flow-normalized nutrient concentrations over time at the current levels; sediments need to show reductions over time at Richland (USGS 07048780).***

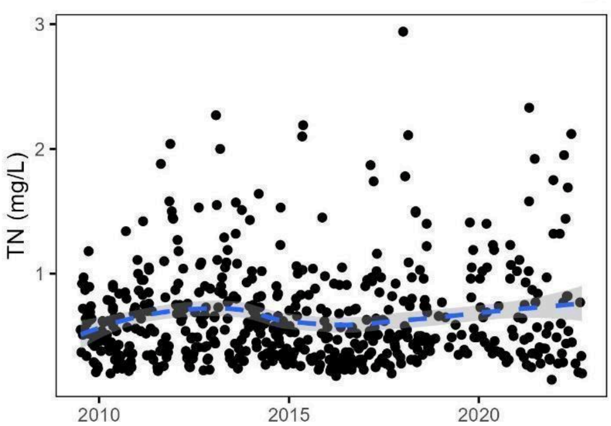
However, the further downstream site (RC45, USGS Site 07048800) showed short-term increases in nutrient inputs into Beaver Lake but no changes over the short-term in sediment inputs. However, this site lacks recent water-quality and discharge data to understand recent changes in nutrient and sediment inputs into Beaver Lake. It might be worth considering the re-establishment of this monitoring site in the future to see how water quality has changed since the past data collection efforts.

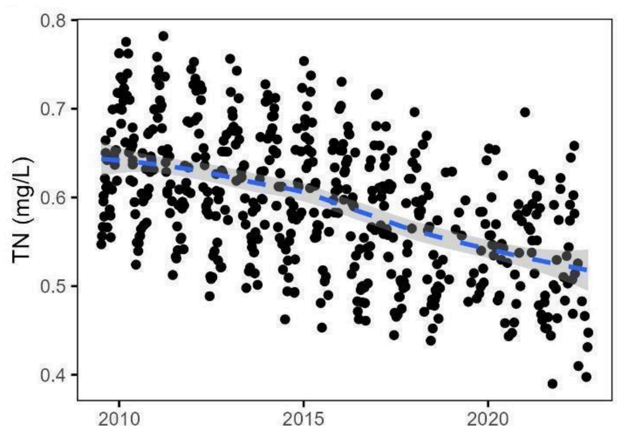
War Eagle Creek

The War Eagle Creek watershed might be the most important focus, given RTI International's modeling to identify hotspots for nutrient and sediments (i.e., NLDPlus catchments) transport potential to Beaver Lake. At War Eagle Creek (WEC, USGS 07049000), nutrients show some divergence in trajectory, where TP shows a decreasing trend (improving water quality) and TN an increasing trend (decreasing water quality); sediments have not shown much change over time. ***The environmental goals for this monitoring site would be to see continued reduction or even potentially maintaining flow-normalized TP concentrations over time at the current levels, whereas the goal would be to change the trajectory of TN to decreases over time; sediments need to show reductions over time at this watershed.***

Beaver Lake

While the goals for the major inflows into Beaver Lake are desired directional changes in water quality, or even maintenance of existing flow-normalized concentrations, the goals at Beaver Lake are a bit different. Beaver Lake at Hickory Creek has applicable WQS for chlorophyll-a (growing season mean, 8 µg/L) and Secchi depth (annual average, 1.1 m), which provide hard end points for water quality and watershed management. ***The environmental goals for Beaver Lake would be meeting the site-specific WQS and de-listing from Arkansas's DEQ 303D List, which the directional changes desired in the inflows should help attain.***





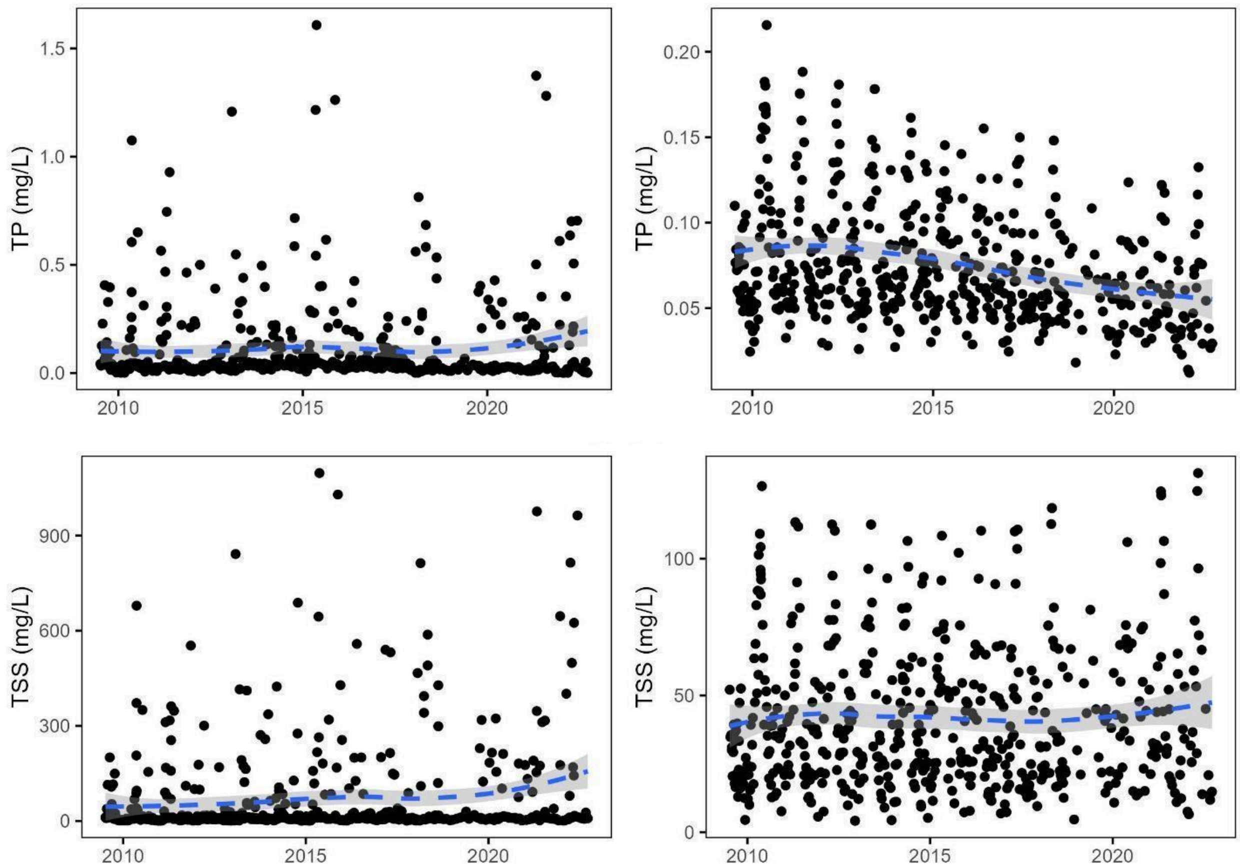


Figure 4-11. Observed Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Sediment (TSS) Concentrations at the West Fork White River (WFWR) near Fayetteville, Arkansas at Molly Wagnon Road Bridge (USGS Site 07048550) from the Arkansas Water Resources Center (AWRC) (left) and Flow-normalized Concentrations from Weighted Regression on Time, Discharge, and Season (WRTDS) Modeling on the Concentration and Discharge Relations over Time (More Details, See Grantz and Haggard, 2023); the Dashed Blue Lines Represent Changes over Time, and this Section Focused on the Changes in Flow-normalized Concentrations over Time Providing Context to the Updated Watershed Protection Strategy (Dashed Blue Line, Right).

Monitoring to Achieve Environmental Goals

The most important part of the monitoring plan is the continued water-quality sampling at Beaver Lake (Hickory Creek) and the existing USGS stream discharge gages within the Beaver Lake watershed, especially the major inflows – Richland Creek, War Eagle Creek, and the White River. The site on Beaver Lake at Hickory Creek has been monitored monthly by the AWRC and District, and the water quality parameters of interest to this strategy and goals, include TN, TP, TSS, Secchi depth, and chlorophyll-a. The current sampling frequency (i.e., monthly) is adequate to assess compliance with existing WQS, which directly relates to the desired water quality targets at this site. The environmental goal would be WQS attainment.

The Beaver Lake Watershed is relatively data rich at the major inflows and select other sites where existing USGS stream discharge gages exist. These sites including Richland Creek (Richland), Town Branch (TB), War Eagle Creek (WEC), West Fork White River (WFWR), White River (Wyman and WR-Elkins) are currently monitored by the AWRC, the District, and the ANRD 319 NPS Program; the most recent AWRC and ANRD contract also added Brush Creek near Arkansas Highway 45 (BC45) to the list of monitoring sites within the Beaver Lake watershed. Water-quality data and estimated discharge are available at BC45 back to 2021, when the Alliance funded the AWRC to monitor select sites within the Brush Creek watershed (Austin, Grantz and Haggard, 2024). The current sampling frequency is roughly 30 times per year, where the AWRC tries to sample across the range of observed discharge at this site; at least one sample per month is generally collected during low flow, and the remaining samples are collected to target seasonal baseflow variation and rainfall-runoff events. The parameters of interest to this strategy include TN, TP and TSS from these water samples, but the various water-quality monitoring projects may analyze samples for other parameters, including anions, bacteria, conductivity, dissolved nutrients, and turbidity. The current sampling frequency is adequate to evaluate changes in flow-normalized concentrations of TN, TP, and TSS over time using WRTDS, which directly relates to the desire to use directional change – improving water quality or decreasing nutrient and sediment input to Beaver Lake – as the environmental goal.

This strategy will need to be adaptive, shifting focus on nutrient and sediment hotpots in other watersheds, if the directional changes (i.e., decreasing TN and TP) shift in watersheds that are currently suggesting that water quality is improving.

Potential Monitoring Gaps and Future Needs to Strategy Updates

Watershed models like WaterFALL used to prioritize NLDPlus catchments are usually calibrated based upon available data, which is often limited to larger watersheds where USGS stream discharge gages and water-quality data exist. In this updated strategy, WaterFALL was calibrated and validated at five sites including Brush Creek, Richland Creek, War Eagle Creek, the White River, and the West Fork of the White River. Excluding the Brush Creek Watershed, the watersheds were relatively large, ranging from 76,800 to 256000 acres, representing a mix of land uses, nutrient and sediment sources, and hydrology. Watershed models calibrated at the large scale like this often do not [accurately] predict hydrology nor nutrient and sediment loads at the smaller watershed scale, e.g. NLDPlus catchments used to identify nutrient and sediment hot spots or priority area for implementation of BMPs and conservation practices to reduce nutrient and sediment loss from the landscape. These models often do not capture streambank erosion as a potential source of sediment loading, and watershed efforts have shown how important this source of sediment is in watershed management efforts to improve water quality.

If watershed models are going to be used to identify nutrient and sediment hotspots (i.e., NLDPlus catchments) within the Beaver Lake Watershed, then water-quality and discharge data are needed at smaller watershed scales to help validate these hot spots predicted by watershed models. Ideally, USGS stream discharge gages would be used to provide the estimate of mean daily flow needed, but other low-cost methods could be used to provide a record of mean daily flows (e.g., see Lasater et al., 2022). Water samples would need to be collected across the range of mean daily discharge to facilitate load estimates from these smaller watershed (e.g., NLDPlus catchments), using appropriate statistical techniques (e.g., WRTDS, or even simple log-log regression techniques with bias correction if needed). ***The data gaps are TN, TP, and sediment loads at a scale relevant to watershed management, and this strategy would recommend focusing on the hotspots identified within the War Eagle Creek watershed***. These data could then be used in a post-model validation framework to evaluate the adequacy of simulated nutrient and sediment loads used in this strategy update (McCarty et al., 2016).

While numerous stream discharge gages across the Beaver Lake watershed might not be feasible, additional water-quality data across smaller watersheds (e.g., NLDplus catchments) would still be beneficial to validate hotspots identified by the watershed modeling exercise. Water-quality (i.e., TN and TP concentrations) during seasonal base flow can be used to inform watershed management strategies and further refine nutrient hotspots for management actions (McCarty and Haggard, 2016). The idea is that stream nutrient concentrations observed during seasonal base flow conditions are positively correlated to elevated nutrient conditions during surface runoff conditions; simply, high nutrient concentrations during seasonal baseflow, which can be easily measured, mean high concentrations during flow conditions following rainfall-runoff. The watershed characteristics which influence stream nutrient concentrations, i.e. catchment land use in the Beaver Lake watershed (e.g., Haggard et al., 2003; Migliaccio et al., 2007; Giovannetti et al., 2013), also result in increased runoff from the landscape. ***A data gap would be watershed-wide nutrient concentrations during baseflow conditions that could be related to watershed characteristics to help refine nutrient hot spots (e.g., see McCarty et al., 2018).*** This data gap could be filled by supplementing existing water-quality monitoring through citizen science programs (e.g., StreamSmart) and directed sampling to target the potential nutrient hotspots identified.

If watershed models are going to be used to identify nutrient and sediment hotspots and these models do not include streambank erosion, then a comprehensive assessment of stream banks and erosion potential are needed within the Beaver Lake watershed. In fact, most watershed models may have complex subroutines to estimate erosion from the landscape and sediment transport within the fluvial channel, but these models often do not specifically include stream bank erosion. The purpose of a comprehensive and watershed-wide assessment would be to identify locations of streambank instability and prioritize reaches for restoration to reduce nutrient and sediment inputs into Beaver Lake. ***A wide range of techniques can be used to characterize streambank erosion hot spots, including bank pins, bank stability indices, historic digital photography, etc, and a combination of these techniques would likely be needed to address this data gap across the Beaver Lake watershed and prioritize reaches for restoration.***

Discharge and water quality data are always a data gap, because the Beaver Lake watershed is both data rich (i.e., long-term hydrology and water quality at major inflows) and data poor (i.e., limited hydrology and water quality at smaller-scale watersheds). These monitoring efforts can be adjusted, targeted, and supplemented to meet the needs of this watershed protection strategy and the overall goal of decreasing nutrient and sediment inputs to Beaver Lake. The ideal situation would include detailed accounting of all BMPs, streambank restoration activities, and conservation practices implemented across the Beaver Lake watershed to reduce nutrient and sediment loss. ***A data gap is a comprehensive database of these practices (e.g., BMPs, restoration efforts, conservation practices) across the Beaver Lake watershed, where these watershed activities could be tied to water-quality improvements, i.e. decreasing nutrient and sediment concentrations in streams and into Beaver Lake.***

Other Monitoring Needs

- *Observational monitoring*. Are there increasing frequencies of algae blooms, sediment plumes, and/or beach closings in the upper lake and lower lake cove areas? If so, monitoring personnel would track upstream to identify sources of the problem. Are stream channels widening and deepening in urbanizing areas and are sediment islands forming instream? This information would also be fed to the Alliance to determine if the current protection strategy needs to be adapted.
- *Programmatic Monitoring for Core Conservation Practices (CPs).* Are core CPs and other voluntary participation programs working as anticipated? Are landowners participating in conservation and stewardship programs at levels anticipated in the Beaver Lake Watershed Protection Strategy? Are developers and local governments participating at a high rate in the Beaver Lake protection efforts, installing stormwater and channel protection controls on construction sites and new development areas? Refer to the Alliance Watershed Success Metrics for a full list of metrics to help determine adaptive management.

These early warning indicators, used together, would suggest when the lake's protection targets are not being met and voluntary efforts are not sufficient, and determine when the Strategy needs to be adjusted. These efforts would be part of the Alliance's adaptive process for management of the watershed.

Citizen science and volunteer-based programs play an increasing role in water quality monitoring. For example, Beaver Lake Secchi Day, which is organized by the District, provides invaluable data on the lake. It is both an important monitoring tool and community engagement effort. StreamSmart, started in 2012, is a voluntary citizen science-based monitoring program that helps to increase the extent and frequency of water quality monitoring in the Beaver Lake watershed. This program was developed by the Beaver Water District, Audubon Arkansas, and the AWRC, and is now administered by H2Ozarks. The goal of the program is to eventually gather seasonal data on water quality at an additional 30 locations throughout the watershed. Citizen volunteers undergo training and then collect data at predetermined monitoring sites. Water samples are analyzed by the AWRC, and data analysis occurs by various groups (e.g., see

Grantz, Haggard, & BENG 4973/5973, 2023). Quality assurance protocols include data quality verification through random duplicate sampling by the AWRC staff. In addition, many Arkansas Master Naturalists train and volunteer their time to assist in volunteer water quality monitoring activities.

Beaver Watershed Success Metrics

To support efforts in adaptive management, The Watershed Success Metrics Framework was developed in 2022 by the Beaver Watershed Alliance in collaboration with the Arkansas Water Resources Center, and Edgewater Coaching & Consulting. The motivation for, and composition of, these metrics are described in Executive Summary of the Watershed Success Metrics Final Report (Grantz, Lewis, & Roark, 2022) included below:

> *"Watershed management organizations need success metrics that provide benchmarks for progress, support programming needs, and help prioritize work. Metrics also serve as communication tools and reporting mechanisms for evaluating impacts and services that these organizations provide. There is a broader need for a centralized, holistic resource for metrics that encompass a full suite of components of watershed success with the potential for standardization of these types of measurements across the many sectors that work together to protect watersheds."*

The Watershed Success Metrics Framework brings together diverse resources on watershed science, building on existing tools and metrics, in a single comprehensive support tool. The Watershed Success Metrics are organized based on three target outcomes:

- SOCIAL: Public and Policy-Maker Prioritization of Healthy Watersheds,
- MITIGATION: Resilient Human Footprint That Does Not Diminish Watershed Function, and
- ECOLOGICAL: Intact and Functional Ecological Systems.

For each of the target outcomes, drivers, indicators, and metrics are identified. Thirteen drivers, which are the actions that "drive" watershed success, are included in the framework. Five are social drivers: education, outreach, community building, legislative encouragement, and address knowledge gaps. Four drivers focus on mitigation of the human footprint: rural land best management practices, low-impact development in urban and urbanizing areas, urban forestry and green spaces, and infrastructure improvements. The remaining four are focused on the ecological function of watersheds: land conservation, natural and cultural preserves, restored ecological function, and synergistic planning.

The Watershed Success Metrics Framework includes 37 indicators and 98 metrics across these 13 drivers. Indicators are the signals that actions are being taken and progress is being made toward watershed success goals, while metrics lay out how that progress will be measured. The final Watershed Success Metrics Framework is formatted as a qualitative self-assessment rubric based on selecting between one of three leadership levels for each metric (Basic, Intermediate, Advanced). Prompts for quantitative assessment, including the current and target metric value are also included, but are clearly labeled as "optional" to encourage participation by a wide range of organizations at any stage of development.

Using the framework is voluntary and at the discretion of the individual organization. The recommended process for using the framework is to first complete the qualitative leadership assessment, followed by filling in metric goals, where available, and, finally, any estimates of current metric values. Adaptive use of the framework is encouraged and may include focusing on priority metrics or converting leadership levels and numeric metric results into a watershed success score."

To access the Watershed Success Metrics Framework, please visit Beaver Watershed Alliance' website at https://www.beaverwatershedalliance.org/watershed-success-metrics-framework/.

4.3 Management Measures, Costs, and Load Reduction Estimates

The four components described in the previous section define the compilation of management measures that have been selected as potential activities for achieving load reductions within the watershed to attain water quality standards (WQS).

Funding for implementation may be obtained from a range of sources ranging from private organizations to local, state, and federal governmental agencies. Private entities such as NWALT and other NGOs may be eligible for similar governmental funding options or may be funded through NGOs or private donations. For this watershed, the District and its Source Water Protection Program provide an annual source of funding for protection actions (Beaver Water District, 2018). Within the region, the Northwest Arkansas Regional Planning Commission provides technical assistance funding.

At the state level, ANRD 319 Nonpoint Source Program grant funding could also be considered for funding land conservation activities. Other sources within DEQ may also supply funding.

There are several federal programs that regularly fund conservation practices. The Environmental Quality Incentives Program (EQIP) and the Conservation Reserve Enhancement Program (CREP) provide incentives and funding for entering into conservation agreements. EQIP is administered by the Natural Resources Conservation Service (NRCS) and CREP is administered by the Farm Service Agency. Lands eligible for EQIP funding include cropland, rangeland, pasture, non-industrial private forestland, and other land on which resource concerns related to agricultural production could be addressed through an EQIP contract. Additionally, NRCS's

Regional Conservation Partnership Program (RCPP) is a partner-driven approach to conservation that funds solutions to natural resource challenges on agricultural land. Within this program, there are two different categories. As specified by NRCS: "RCCP Classic projects are implemented using NRCS contracts and easements with producers, landowners, and communities, in collaboration with project partners. Through RCPP Grants, the lead partner must work directly with agricultural producers to support the development of new conservation structures and approaches that would not otherwise be available under RCPP Classic."

Table 4-7 brings together the core conservation practices discussed among the four components that have shown to be effective within the watershed over the last 10 years or that have been identified through outreach to be acceptable options for landowners. The following informational elements are provided for each of the conservation practices to inform the costs and potential load reductions feasible through their implementation:

- The range in financial assistance (as unit costs) available through federal programs (costs taken from 2023 EQIP or the calculated unit costs of completed projects within the watershed.
- The unit of measure used to demonstrate size and apply unit cost estimates.
- The load reduction efficiency. For each practice there are quantified efficiencies assigned to each practice within the practice community and published tools. Efficiencies provided in this table are guided by EPA Pollutant Loading Estimation Tool and the Chesapeake Bay Program Best Management Practice assessments and guidance.
- Implementation support. Notes on the successful implementation or outcome from the conservation practice within the watershed to date.

For the core practices estimated funding ranges, using the unit costs specified by the EQIP 75 payment schedule for 2023 in Arkansas, are provided where available. The cost evaluations consider the current costs for material and labor within the state and the fair marketplace compensation for opportunity costs that may arise (e.g., conversion of productive land). At the time of publication, the most recent payment schedules for selected conservation activities within Arkansas from the NRCS are available from USDA.

The load reduction efficiencies specified for each practice are the default assumptions used within EPA's Pollutant Load Estimation Tool (PLET) where the BMP names specified within PLET were matched to the corresponding identified conservation practice. While these default efficiencies may vary due to specifics of the practice, site conditions, and engineering designs (as evidenced by the range available), they provide an initial assessment of the extent of load reduction that can be achieved with implementation.

Table 4-7. Assessment of Core Conservation Practices for Beaver Lake Watershed

Conservation Practice (NRCS Code)	Units	Load Reduction Efficiency (TN/TP/Sed)	Financial Assistance Range (EQIP 75)	Implementation Support
Agricultural/Working Land Practices				
Nutrient Management Plan Design and Implementation Activity (157)	N/A	TN: 15% - 24% TP: 45% - 56%	$3,244.50 - $8,273.48	Nutrient management plans and poultry litter management plans are required in the watershed due to the watershed's state designation as a Nutrient Surplus Area. Interviews with resource agencies and poultry integrators indicated a high level of compliance with the Nutrient Management Plan requirements.
Nutrient Management (590)	Ac	TN: 15% - 24% TP: 45% - 56%	$6.60 - $54.07	
Poultry Litter Management Plan	N/A	TN: 14% TP: 14%		
Agricultural Ponds (378)	CuYd	TN: 35% TP: 45% Sed: 60%	$3.00 - $5.65	Locations with headwater agricultural ponds that could be assessed for retrofitted to provide stormwater control have been identified for the watershed (Figure 4-8).
Fence (382)	Ft	TN: 15% -75% TP: 22% - 75% Sed: 58% - 75%	$1.63 - $3.86	Cattle grazing was identified as an issue in the District Source Water Protection Plan (Beaver Water District, 2018). Riparian parcels that are primarily pasture were identified for this study (Figure 4-4). Additionally, the length of the stream through these riparian parcels was calculated by catchment and provides a measure for potential length of fencing needed.
Pasture Aeration[1]	Ac	TN: 49%[1] TP: 37%[1]	$0.01 - $2.49[1]	Pasture aeration was assessed in study of Beaver Lake Watershed by University of Arkansas and USDA NRCS. 44% of survey respondents were willing to pay for pasture aeration.
Conservation Cover (328)	Ac	TN: 8% -20% TP: 7% - 15% Sed: 10% - 20%	$10.66 - $83.84	
Pasture and Hay Planting (215)	Ac	TN:18% TP: 15%	$327.84 - $559.94	

Conservation Practice (NRCS Code)	Units	Load Reduction Efficiency (TN/TP/Sed)	Financial Assistance Range (EQIP 75)	Implementation Support
Land Management				
Conservation Plan (199)	N/A	Variable	$2,445.53 - $10,268.80	Priority natural areas for conservation and preservation were identified for the watershed in Figure 4-2.
Forest Management Plan (106)	N/A	Variable	$1,197.00 - $8,164.80	
Forest Management Practice Design (165)	N/A	Variable	$315.00 - $1,738.80	
Critical Area Planting (342)	Ac	TN: 18% TP: 20% Sed: 42%	$333.21 - $1,103.81	These land management practices have been identified to include when pursuing a program-based approach to NCD and stream restoration that can be pursued for funding. Section 5.1.2 describes completed implementation projects within the watershed.
Mulching (484)	Ac	Sed: 41% - 71%	$35.97 - $1,921.88	
Tree and Shrub Site Prep (490)	Ac	Sed: 69% - 95%	$25.84 - $430.29	
Tree/Shrub Establishment (612)	N/A		$0.22 - $20.94	
Wildlife Habitat Planting (420)	Ac	TN: 18% TP: 20% Sed: 42%	$197.07 - $910.98	
Prescribed Burning Design (160)	N/A		$945.00 - $4,536.00	Prescribed burns have been conducted within the watershed. Training on such practices has been provided to landowners.
Channel/Riparian Restoration				
Streambank Restoration		TN: 15% -95%[4] TP: 22% - 95%[4] Sed: 58% - 95%[4]		Section 5.1.2 describes completed implementation projects within the watershed.
Wetland Restoration (657)	Ac	TN: 42%[5] TP: 41%[5] Sed: 31%[5]	$12.91 - $9,028.20	This practice has been included in at least one successfully completed stream restoration project within the watershed.
Grade Stabilization Structures[2] - Check Dams (410)	Ton		$69.43 - $83.32	
Grade Stabilization Structures[2] - Rock Drop Structures (410)	SqFt		$56.88 - $68.25	

Conservation Practice (NRCS Code)	Units	Load Reduction Efficiency (TN/TP/Sed)	Financial Assistance Range (EQIP 75)	Implementation Support
Riparian Herbaceous cover (390)	Ac	TN: 8% -20% TP: 7% - 15% Sed: 10% - 20%	$209.10 - $266.82	Riparian parcels that are primarily pasture were identified for this study (Figure 4-4). Additionally, the length of the stream through these riparian parcels was calculated by catchment and provides a measure for potential length of riparian buffer to restore. While the specific riparian lengths were not calculated, Figure 4-2 identifies natural areas to pursue riparian vegetation preservation.
Riparian Forest Buffer[3] (391)	Ac	TN: 49% TP: 47% Sed: 59%	$371.41 - $667.78	
Streambank and shoreline protection (580)	Ft	TN: 15% -75% TP: 22% - 75% Sed: 58% - 75%	$11.83 - $303.70	Section 5.1.2 describes completed implementation projects within the watershed.

[1]Efficiencies and cost range were taken from "Profitability Assessment of for Nutrient Runoff Mitigation Practices on Hay Fields and Pastures."
[2]Check Dams and Rock Drop Structure costs provided to align with previous watershed practices.
[3]Provided range for acre costs to align with previous watershed practices.
[4]Upper limits on stream restoration load reduction efficiencies are quantified from completed projects within this watershed.
[5]Source of load reduction efficiencies is from the Chesapeake Bay Program modeling compilation (Chesapeake Bay Program, 2018)

5 Implementation Summary

Considering the strategy presented in Section 4, an overall focus and implementation plan has been developed to allow for actionable results. First, an overall prioritization of the subwatersheds, given the priority watershed issues in the region, is presented in Section 5.1 to highlight key implementation areas. The plan for implementation, including the timeline, potential funding sources, responsible groups for each component of the strategy, is detailed in Section 5.2. Lastly, Section 5.3 includes a description of the Alliance's adaptive management approach.

While this strategy identifies priority locations and target issues for directing programs and projects, the prioritization presented does not preclude any organization from seizing opportunities that may arise (due to funding, emerging needs, or otherwise).

5.2 Overall Prioritization of Subwatersheds

To develop a plan for implementation, it is important to identify key areas for action that can address the most important priorities summarized in the Strategy. However, a perfectly representative aggregation of water quality priorities for both sediment and nutrients, from dozens of sources, is not possible. Therefore, this section presents three different forms of overall priorities to capture the full range of water quality priorities in the watershed: land management prioritization using watershed modeling results (Section 5.1.1), streambank priorities based on WCRC research and field data (Section 5.1.2), and previous prioritizations conducted by other organizations (Section 5.1.3). Considering the factors contributing to all three of these prioritization schemas and the range of results, various stakeholders can determine their priority areas depending on the outcomes desired.

5.2.2 Land Management Prioritization based on Watershed Modeling

Applying results from the WaterFALL model, an overall prioritization for land management was developed through discussions with the Alliance TC. This prioritization highlights which areas, when land cover, land use and current climate are considered, show the greatest potential for improvement given better land management practices. The overall land management prioritization was performed for both baseline and future conditions. The future scenario selected was a "worst case scenario" of projected 2050 land use with a wetter, warmer climate (Section 2.2.1.2). The catchment-level metrics selected by the Alliance TC to incorporate into the prioritization are described in detail in Table 5-1 and include:

- Local, normalized sediment, nitrogen, and phosphorus loads
- High flood pulse count

- Mean annual total runoff
- Pasture riparian length

For the hydrology and water quality metrics, the 75th percentile value for each metric was determined across all catchments within the watershed. Each catchment was then assessed by metric on whether its value exceeded the threshold value, where exceedances denote priorities for that metric (Figure 5-1). In the case of pasture riparian length, the catchment was selected as a priority if the pasture riparian length was greater than 500 feet. A priority score was calculated for each catchment by counting the number of metrics exceeding the corresponding threshold under the baseline scenario. Because six metrics were chosen for the assessment, the highest priority catchments are those with four or more metrics exceeding thresholds (Figure 5-1). A corresponding map was developed for the watershed under future conditions as well to assess not only current issues but potential issues into the future as the land development and climate changes.

As shown in Figure 5-2, the key priority land management areas are mostly concentrated in the Brush Creek, Richland Creek, and War Eagle Creek watersheds. These priorities appear to concentrate in the more agricultural areas of the watershed and are partially due to the inclusion of (1) pasture riparian stream length implementation priority and (2) water quality metrics influenced by land cover and land use. Looking ahead to the future, the greatest priority areas expand towards the White River subwatersheds. There is also a concentration of catchments along the western boundary of the watershed surrounding Fayetteville that have the highest priority in both the baseline and future scenarios. These areas identify the need for land conservation under urbanizing land conditions.

The modeling underlying these findings included sources from surface concentrations in runoff from rural lands, exponential build-up and wash-off from urban lands, manure application of nitrogen and phosphorus to pasture lands, nitrogen from septic systems, groundwater contributions through baseflow, and streambank erosion. As noted previously, due to data constraints, streambank erosion was only conservatively included in the model, and is not fully represented by these results, especially given the White River subwatershed is known to be a larger source of sediment and phosphorus load to the streams according to local field measurements. Therefore, prioritizations for streambank and river restoration are considered separately (RTI International, 2022).

The identified priority catchments provide localized areas to target for conservation practices. Given the land uses and additional sediment and nutrient sources (i.e., septic system counts, manure loadings) within the identified priority catchments, the applicable conservation practices can quickly be identified and the potential for implementation, given the land parcels that fall within the catchment, can be assessed.

Table 5-1. Land Management Priority Metrics: Definitions and Interpretations

Land Management Priority Metric	Definition	Units[1]	Metric Interpretation	Notes for the Metric
Hydrology Metrics				
High Flood Pulse Count	High flood pulse count. Computes the average number of flow events with flows above a threshold equal to the 75th percentile value for the entire flow record.	# of events/yr	Average count of high flow events within a year on average. A higher value indicates a greater frequency of high flow events.	An increase in value means there is an **increase in frequency of high flow events**. [1]
Mean Annual Total Runoff	Mean annual total runoff. Computes the total runoff for each year in the assessment period and then computes the mean of the annual values (in – depth).	cm/yr	Depth of mean annual total runoff. To determine runoff volume, multiply by the land area in the catchment.	An increase in the mean annual total runoff indicates **runoff from the surface and thus cumulative flows will be increasing**.
Water Quality Metrics				
Local, Normalized Sediment Load	Mean annual sediment generation per unit area. Compute the mean annual total sediment load and divide it by the catchment area (lbs/mi^2 – loading rate).	lbs/mi^2	The rate of sediment generated within a catchment per unit area provides a comparable value among catchments.	An increase in the sediment loading rates means **more sediment is being generated within the catchment.**
Local, Normalized Nitrogen Load	Mean annual nitrogen generation per unit area. Compute the mean annual total nitrogen load and divide it by the catchment area (lbs/mi^2 – loading rate).	lbs/mi^2	The rate of nitrogen generated within a catchment per unit area provides a comparable value among catchments.	An increase in the nitrogen loading rates means **more nitrogen is being generated within the catchment.**
Local, Normalized Phosphorus Load	Mean annual phosphorus generation per unit area. Compute the mean annual total phosphorus load and divide it by the catchment area (lbs/mi^2 – loading rate).	lbs/mi^2	The rate of phosphorus generated within a catchment per unit area provides a comparable value among catchments.	An increase in the phosphorus loading rates means **more phosphorus is being generated within the catchment.**
Additional Priorities				
Riparian Pasture Length	Riparian pasture length (feet). The length of the flowline within the selected primarily pastureland parcels.	Feet	Using the selected parcels, the length of the stream channel (i.e., flowline) within the parcel area is calculated. This metric serves as a surrogate for potential stream restoration projects.	Priority is assigned to catchments with more than 500 feet (152.4 meters) of stream channel length. ***The 500 linear foot threshold is used to identify catchments with larger spans of riparian area affected by agriculture from which suitable stream restoration projects can be sited***

[1]The metric is based on a threshold set by assessing the flow data in the baseline, current conditions scenario. The metric values across scenarios therefore are all calculated based on the same catchment specific thresholds and differences from baseline measure the increase or decreases from current conditions.

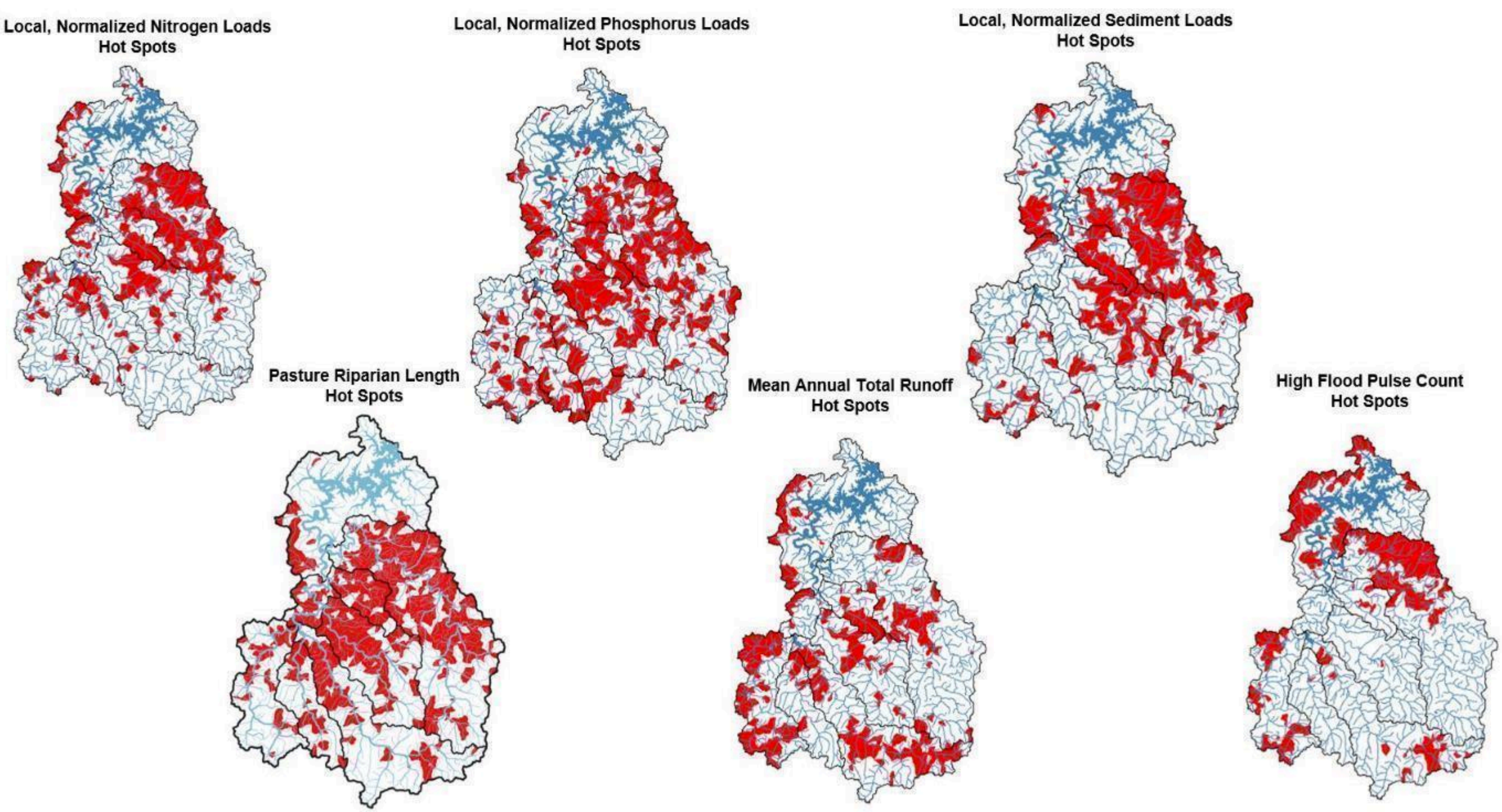
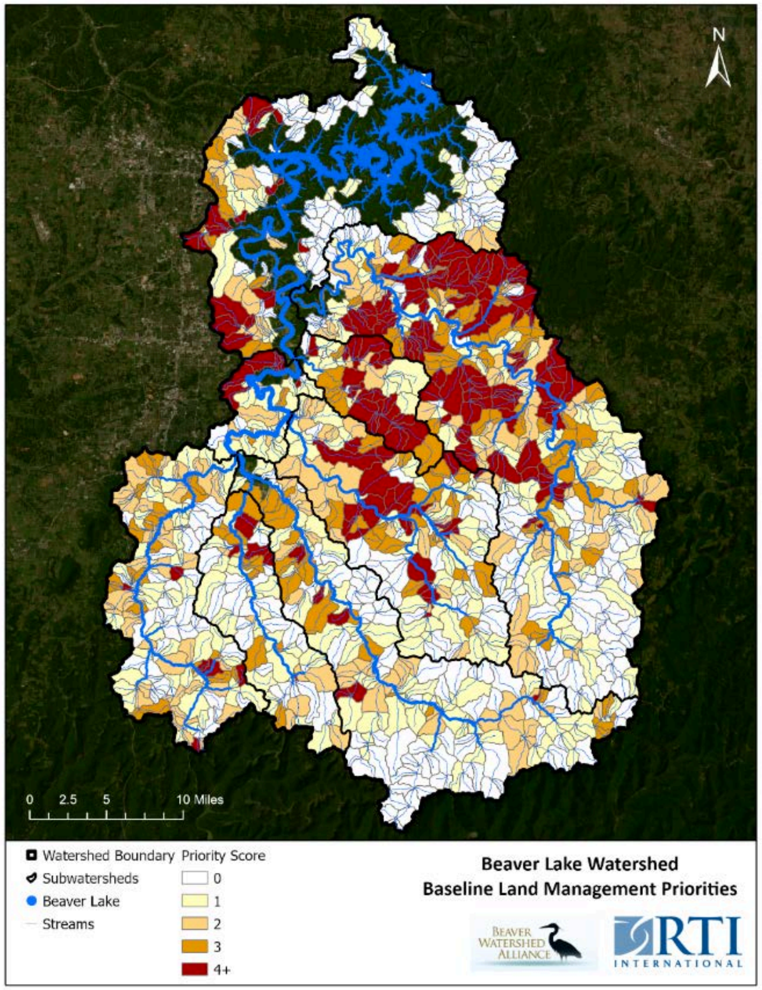


Figure 5-1. Baseline Scenario Threshold Maps (NLDPlus Catchment Hot Spots) for Each of the Selected Land Management Priority Metrics, including Normalized Nutrient and Sediment Loads, Pasture Riparian Length, Mean Total Runoff, and High Flood Pulse Count within the Beaver Lake Watershed.



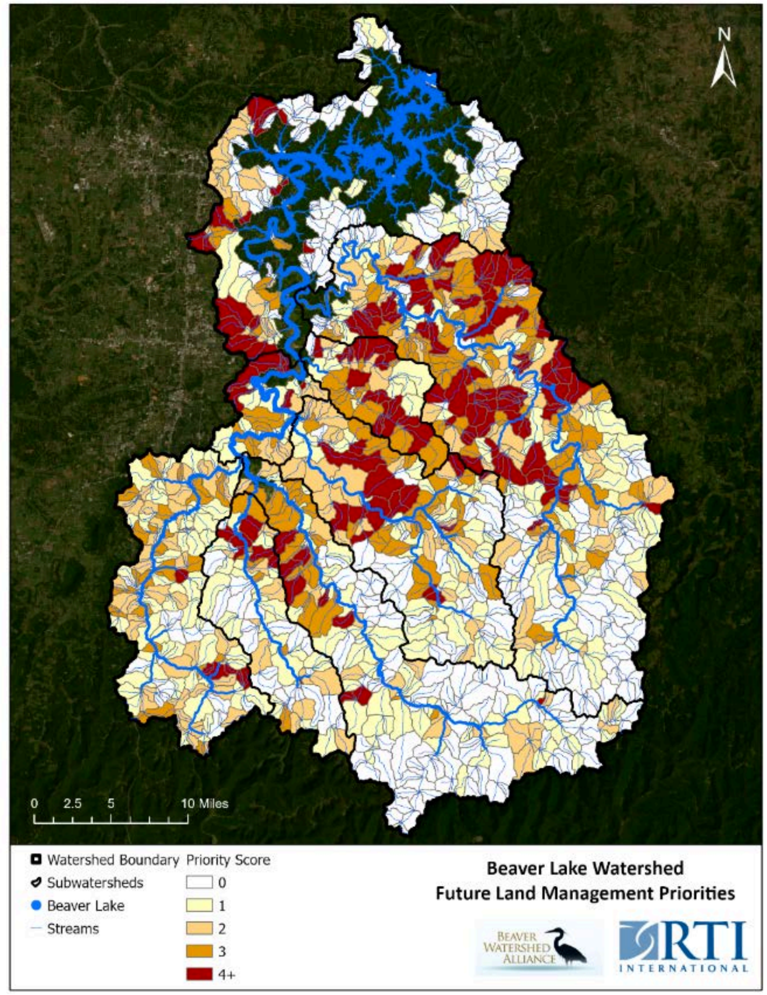


Figure 5-2. Overall Baseline and Future Land Management Priority NLDPlus Catchments within the Beaver Lake Watershed.

5.2.3 Streambank Priorities based on WCRC Field Results

This section was contributed by Sandi Formica and Matthew Van Eps from the WCRC.

As previously noted, sediment and nutrient loadings resulting from streambank erosion are higher compared to unpaved roads, pasture lands, silviculture, construction, and other sources identified in the watershed (ADEQ 2004). The cost to implement river and streambank restoration can be significant and is related to the size of the watershed area at the site and the level of instability that generally equates to sediment loading. The larger the river, the more construction materials will be required, more excavation and grading of materials will be required because of the greater volume, larger heavy equipment will be required which increases rental costs, and additional revegetation materials and labor will increase. All of this increases the cost of to construct a project. However, the cost per ton of sediment reduced can be much less when compared to the unit-based reduction costs achieved by BMPs that address other sources of concern. When funding is available, and landowners are volunteering to implement this practice on their property, river and streambank restoration should be a priority in the Beaver Lake watershed to reduce pollutant loadings and protect water quality based on the cost-effective nature of the practice.

5.2.3.9 Priority Sites for the WFWR

The WFWR watershed can be used as a template of how, when data documenting streambank erosion is available for consideration, efforts can be targeted as part of a prioritized approach to watershed planning. The WFWR is one of six tributaries to the White River and Beaver Lake, and it was identified in the 2012 Strategy to be a significant source of sediment and phosphorus resulting from streambank erosion. The most unstable reach in the WFWR watershed, approximately one mile in length and identified as needing restoration of channel instability, had annual sediment loadings of over 15,000 tons per year from accelerated streambank erosion. Twenty-eight reaches and 25 individual streambanks were identified as needing restoration (Formica & Van Eps, 2010) and funding was needed to address the miles of channel instability to reduce sediment and nutrient loading from this source. The WCRC worked with the NRCS, the District, the Alliance, and other partners to develop the *"WFWR Watershed Plan-EA"* to address channel instability and resulting accelerated streambank erosion along the WFWR and its tributaries utilizing NCD principles by designing, constructing, and maintaining large-scale river restoration projects involving the cooperation of multiple landowners, utilizing the PL-566 authority (USDA NRCS , 2021); the plan was approved in October 2020. The plan provides recommended project sites where river restoration should be implemented to address critical, watershed-scale erosion and reduce sediment loadings to the WFWR and Beaver Lake Watershed. The sites identified as needing restoration were prioritized into three groups as shown in Figure 5-3 and should be used as a guide to select sites for funding. The *"WFWR*

Watershed Plan" and NRCS PL-566 authority is a funding source for additional restoration design and implementation of priority sites in the WFWR watershed.

5.2.3.10 Priority Sites for Other Subwatersheds

Streambank erosion monitoring has been conducted in other subwatersheds within Beaver Lake Watershed. The Alliance requested that the WCRC evaluate erosion rates and calculate sediment and nutrient loadings at eighteen individual sites, often with multiple eroding streambanks, based on landowner interest in the Middle Fork of the White River (MFWR), Upper White River – Lake Sequoyah, War Eagle Creek, WFWR, and Beaver Lake – White River. Annual sediment and phosphorus loadings were found to range from 38 to 14,700 tons and 22 to 7,100 pounds, respectively. The wide range in the results supports the importance of taking a comprehensive watershed approach to addressing streambank erosion and prioritizing sites for restoration. Funding availability will always be a factor in site selection, because often the more unstable the site, the more expensive it may be to implement the restoration plan. The WCRC is currently evaluating river instability and streambank erosion for the MFWR watershed. Reaches of river in need of restoration will be identified and prioritized. This information can be used as part of the updated Strategy once it is available. As funding becomes available to evaluate other watersheds, this information should be used as part of the planning process over the next ten years.

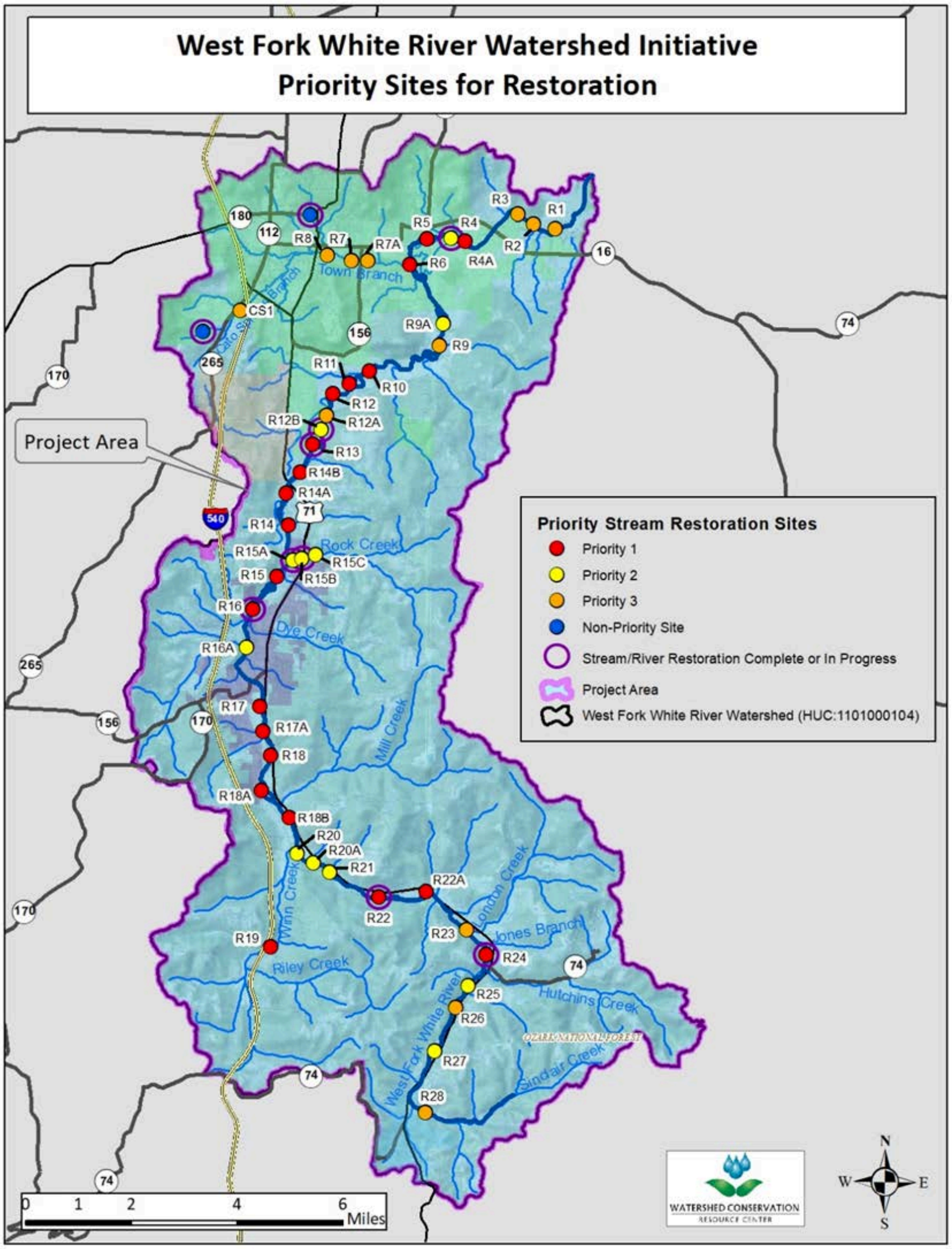


Figure 5-3. Reaches of the WFWR and Tributaries Identified as Needing Restoration in the WFWR Watershed Plan That Is Authorized by the NRCS PL-566 Program.

5.2.3.11 Examples of Implementation of River and Streambank Restoration and Subsequent Load Reductions

With the support of the watershed assessment (Arkansas Department of Environmental Quality, 2004) and streambank erosion monitoring and evaluation, several restoration projects have been funded through grant programs and local matching funding. Near the Fayetteville Municipal Airport, over one mile of the WFWR has been restored and Figure 5-4 presents before and after photographs of the lower end of the Phase II project funded through the NRCS RCPP and PL-566 programs. Through an NRCS RCPP project, several small streambank restorations were designed and implemented on tributaries to the WFWR by combining NCD principles and NRCS land management practices. Figure 5-5 shows an example of a streambank restoration on Rock Creek in which the stream channel was realigned, and the streambank was reconstructed utilizing NCD principles. Twelve restoration projects have been implemented to-date in the WFWR and a summary of the sites and sediment and phosphorus annual load reductions are shown in Table 5-2. When combined, these sites reduce sediment and phosphorus loadings by at least 18,500 tons/yr and 7,500 lbs/yr, respectively (Table 5-2) to the Beaver Lake watershed.

Table 5-2. Summary of Sediment and Phosphorus Annual Load Reductions from River, Stream, and Streambank Restoration Projects in the WFWR in Beaver Lake Watershed (WCRC, 2022).

2010 -2022	Project name	Wastershed Area (mi2)	Length (ft)	Date Completed mm/yy	Riparian Protected-Restored (ft)	Wetlands Restored	Sediment Reduced ton/yr	TP Reduced lb/yr	Cumulative Reduction Over Time Sediment ton/yr	TP lb/yr
Early Restoration	WFWR - Brentwood	18	1,800	05/10	3,600	x	1,880	640	22,873	7,787
	Mullins Creek - U of A	0.75	1,000	09/12	2,000	x	52	24	511	236
	WFWR - Fayetteville Airport Ph. 1	83	4,600	02/15	9,200	x	4,072	1,817	30,201	13,476
	WFWR Dead Horse Mtn. Rd	120	2,500	07/15	5,000	x	1,860	1,080	12,974	7,533
	Ground Cherry Creek - Kessler Mtn. Reg. Park	0.75	2,000	06/16	4,000		61	48	371	292
RCPP WFWR Watershed Initiative	WFWR Fayetteville Airport Ph. 2	83	1,400	02/21	2,800	x	5,500	1,330	7,792	1,884
	Rock Creek - Ph. 1	6	300	03/19	600	x	1,830	900	6,100	3,000
	Rock Creek - Ph. 2	6	300	07/21	600	x	986	571	986	571
	Unnamed Trib. WFWR 1	2.3	300	10/20	600		-	-	-	-
	Unnamed Trib. WFWR 2	0.8	50	07/19	100		-	-	-	-
Post RCPP	WFWR - Brentwood Mountain	33	1,600	03/22	3,200	x	2,200	1,140	648	336
	Tanglewood Branch	0.5	1,000	07/22	2,000	x	33	12	0	0
TOTAL			16,850		33,700		18,474	7,562	82,455	35,115

NCD principles were successfully used to design and implement a streambank restoration on the White River at 400 square miles in 2012. The project prevents 3,600 tons/year of sediment and 3,600 lbs/year phosphorus from entering the White River and is shown in Figure 5-6. The streambank restoration continues to protect pasture lands with high phosphorus and metals concentration from the previous application of wastewater treatment solids.

Figure 5-4. Upper: Accelerated Streambank Erosion along the WFWR near the Fayetteville Municipal Airport. Lower: The Same Area as above after River Restoration Implementation in 2020.
This section of the project reduces sediment loadings by 5,500 tons/yr and phosphorus loadings by 1,330 lbs/yr to the Beaver Lake Watershed. The restoration restored the stream channel, riparian areas, floodplains, and wetlands and was funded through an NRCS RCPP and under the PL-566 authority.

Figure 5-5. Streambank Restoration on Rock Creek, a Tributary to the West Fork White River. Left Is Rock Creek before Restoration (2019) and Right Is the Same Site Two Years Following Implementation of Restoration Design (2021).

Figure 5-6. Streambank on the White River.
Upper shows eroding streambank; Bottom is restored streambank in 2017. Project was constructed in 2012 and protects lands that were historically used for land application of wastewater treatment solids. The project prevents 3,600 tons of sediment and 3,600 pounds of phosphorus from entering the White River and the Beaver Lake watershed, annually.

5.2.4 Previous Prioritizations

There have been several studies performed in the region that the team referenced for context and comparison. Some studies have investigated methods of prioritizing regions in the watershed. These studies include relevant information referenced throughout the study and can allow for comparison and complementing of the prioritization performed by the RTI Team (RTI International, 2022):

- Beaver Lake SWAT Modeling Baseline Analysis, performed by Tetra Tech, was a study modeling all areas upstream of Beaver Lake during the period 1995 to 2006 and projected for the year of 2055, demonstrating projected land use change, increased sediment load (+26.3%), decreased phosphorus load (-1.7%), and slightly increased nitrogen load (+3.7%) (Tetra Tech, 2009); this effort formed the basis of the 2012 WPS.
- USDA NRCS has also determined Source Water Priority Areas, updated for the Fiscal Year of 2022 shown for the state of Arkansas in Figure 5-7. In a national bulletin (National Bulletin 300-22-42), the USDA NRCS also references geospatial data modeled by the EPA for the percent of watershed land area in a surface water Source Protection Area (SPA) for each HUC12 (Figure 5-8). While these priorities shown in Figure 5-7 and Figure 5-8 are based on national data sources and consequently lower resolution than the priorities found in the study, they can be considered in addition to the priorities the study has found.

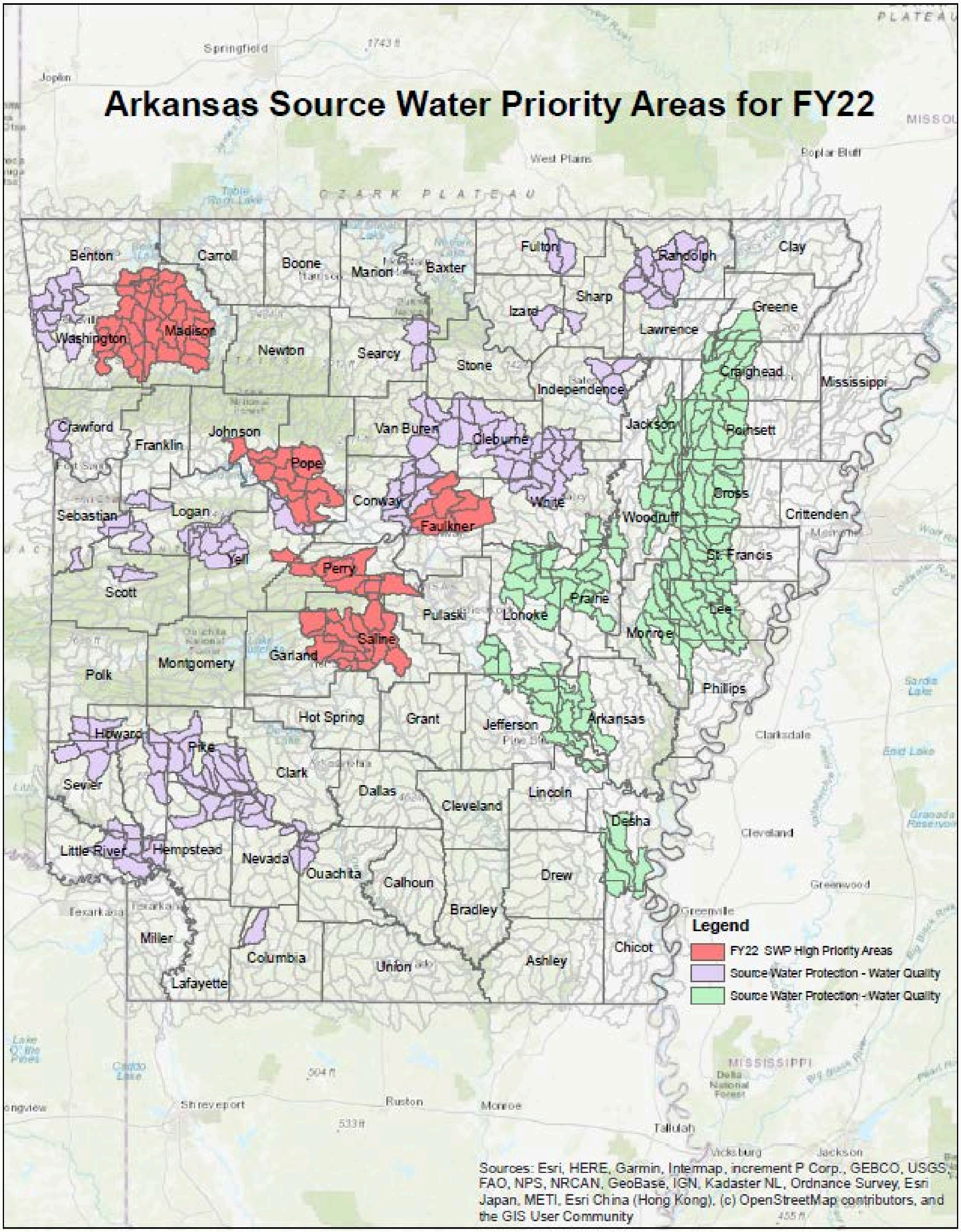


Figure 5-7. NRCS Arkansas Source Water Priority Areas for Fiscal Year 2022. (Source: NRCS)

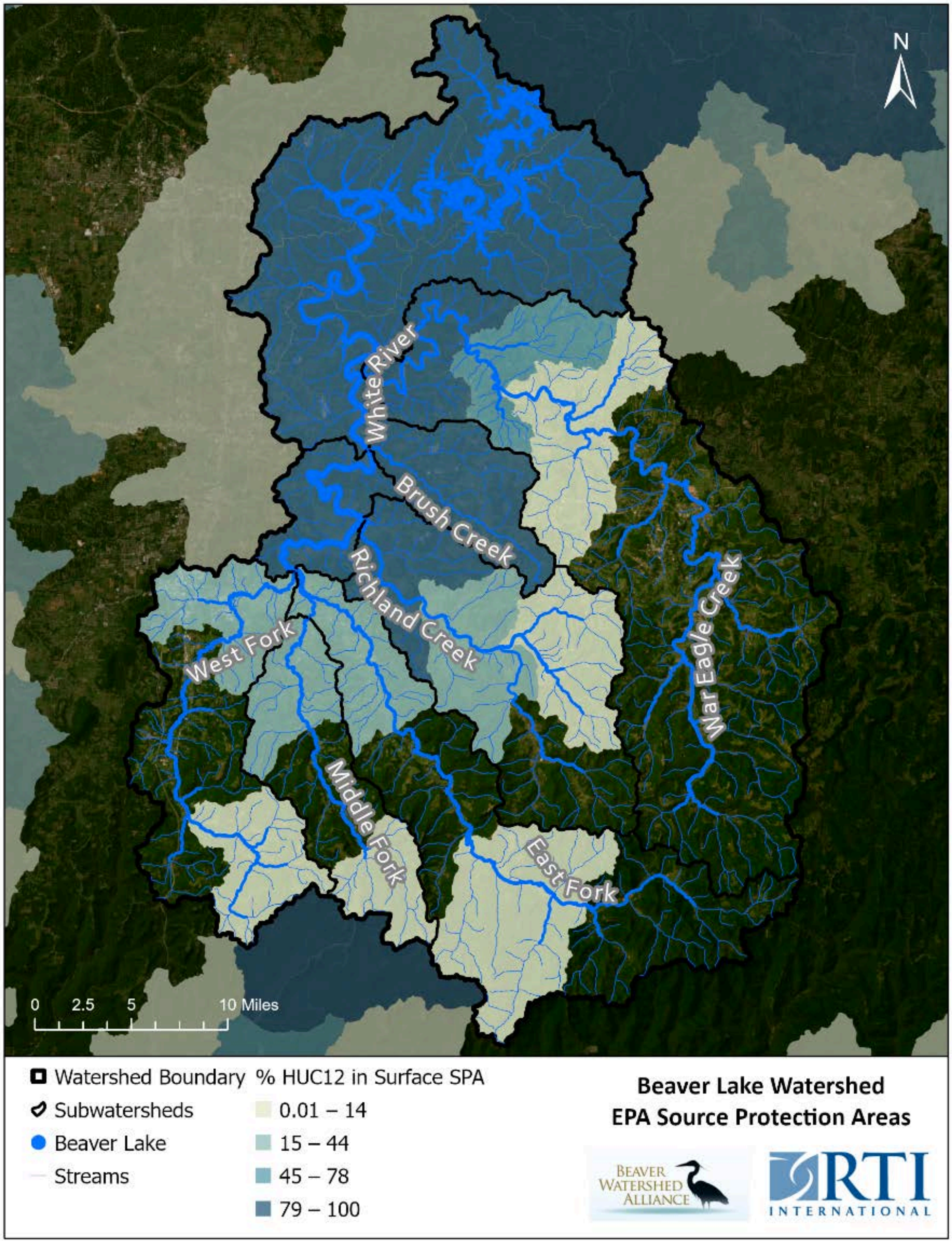


Figure 5-8. Percent of Hydrologic Unit Code 12 (HUC12) Subwatersheds in EPA Surface Source Protection Areas (SPA) within the Beaver Lake watershed.

5.3 Implementation Timeline

The timeline suggested for implementation of components of this strategy includes short-term (i.e., ~2 year), mid-term (~5-8 year), and longer-term or ongoing actions. Implementation of the four key components of the Protection Strategy constitute the short-term actions: (1) Beaver Watershed Alliance activities; (2) implementation of key conservation practices; (3) education and outreach; (4) managing a monitoring and adaptive management program. The Alliance would be an appropriate organization to manage short-term actions, though this watershed group certainly is not the only organization that should implement the Strategy, as many local, state, and federal agencies and groups are also accountable for the implementation.

Table 5-3 provides a snapshot of the key actions recommended in the Strategy, the potential funding and assistance, who needs to take the lead, and other groups responsible for implementation. As can be seen, there is much work to do and success will depend on many agencies, community leaders, and landowners.

Table 5-4 provides an estimated timeline or schedule for acting, with shorter-term priority actions denoted. Mid-term actions will be the further development, refinement, and operation/maintenance of the four key components. Long-term actions will be the ongoing operation/maintenance of the key components and related programs as described above, and will also include new programs and actions, such as monitoring and adapting the Strategy.

Implementation capability will depend on many factors, including available funding and resources and other community priorities requiring attention. In this regard, this section should be viewed as a guide to help the Alliance and others implement the Strategy. Estimated timelines are not absolute, but rather based on best available information.

Table 5-3. Beaver Lake Watershed Protection Strategy Implementation Summary

Protection Strategy Component	**Potential Funding/Assistance**	**Responsible Group(s)**
Component #1 Beaver Watershed Alliance		
Review/Update as needed the Beaver Lake Watershed Protection Strategy *Assume five-year adaptive management cycle	• Local governments • Local water suppliers • Foundations • ANRD	• Lead: Beaver Watershed Alliance
Identify dedicated funding sources for operations and implementation of Strategy Components	• Local businesses • Local governments	• Lead: Beaver Watershed Alliance

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
	• Local water suppliers • Foundations • ANRD	
Component #2 Conservation Practices		
Land Conservation: Conservation Easements & Conservation Agreements • Identify Conservation Easements for Stream Buffers and Upland Areas • Conduct screening and field evaluation of priority areas • Conduct landowner outreach • Secure funding sources • Develop stewardship plan • Explore Transfer of Development Rights Program • Explore Carbon Credit Program	• State and federal tax credits e.g. Arkansas Wetland and Riparian Zone Tax Credit • NRCS Initiatives and Funding Opportunities such as land conservation practices • Local water suppliers • Local businesses • Local governments • Trust for Public Lands (technical assistance only) • The Nature Conservancy (technical assistance only)	• Lead: Local Land Trust Organizations, including Northwest Arkansas Land Trust and the Ozarks Land Trust • Beaver Watershed Alliance • NWA Regional Planning Commission (NWA Open Space Plan and other strategies) • Local water suppliers • Natural Resources Conservation Service • Local water suppliers • Local governments • The Nature Conservancy • Other Land Trusts
Land Restoration • Conduct screening and field evaluation of priority areas for riparian, pasture, forest, prairie, glade, wetlands, unpaved roads and urban greenspace restoration sites • Conduct landowner outreach • Secure funding sources • Identify/secure stewardship organizations	• State and federal tax credits e.g., Arkansas Wetland and Riparian Zone Tax Credit	• Lead: Beaver Watershed Alliance and Restoration/Conservation groups • Arkansas Dept of Agriculture - Forestry Division • University of Arkansas Division of Agriculture – Cooperative Extension Service

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
• Develop stewardship plans		
Unpaved Road Improvements (emphasizing retrofits including ditch hydroseeding, water bars, wing ditches, and stream crossing stabilization)	• ANRD – Unpaved Roads Program (public roads) • The Nature Conservancy – Unpaved Roads Program (public roads) • NRCS Initiatives and Funding Opportunities such as land conservation practices for private unpaved roads • Legislative appropriations • Local government road maintenance funds	• Lead: Local governments • Beaver Watershed Alliance • ANRD • NRCS • The Nature Conservancy
River Restoration, Streambank Restoration, and Stream Stabilization • Identify unstable streambanks and prioritize sites • Conduct field evaluations • Conduct landowner outreach • Coordinate with US ACOE, ADEQ and other permitting agencies • Coordinate with cities on trails and infrastructure near waterways • Develop preliminary designs and cost estimates • Secure needed permits	• Local water suppliers • Local businesses • Local governments • Foundations • ANRD – 319 grants • Federal Stimulus Funds • State and federal tax credits • NRCS Initiatives and Funding Opportunities such as land	• Lead: Beaver Watershed Alliance and River Restoration Conservation groups • Landowners • Natural Resources Conservation Service • Arkansas Game and Fish Commission • The Nature Conservancy • Local governments (cost share) • Local water suppliers (cost share) • NWA Regional Planning Commission • US Army Corps of Engineers (ACOE)

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
• Secure funding • Secure stewardship organizations • Final planning and design • Develop stewardship plan • Implement	conservation practices • Conservation Groups • Arkansas Stream Team • Wildlife Habitat Incentives Program • State and federal tax credits e.g. Arkansas Wetland and Riparian Zone Tax Credit	
Low Water Crossings – Stream Barriers • Identify instream barriers and prioritize sites • Conduct field surveys and evaluations • Conduct landowner outreach • Coordinate with US ACOE, ADEQ and other permitting agencies • Develop preliminary designs and cost estimates • Secure needed permits • Secure funding • Implement	• Local water suppliers • Local businesses • Local governments • Foundations • ANRD – 319 grants • Federal Stimulus Funds • State and federal tax credits • NRCS Initiatives and Funding Opportunities such as land conservation practices • Conservation Groups • Arkansas Stream Team • Wildlife Habitat Incentives Program	• Lead: Beaver Watershed Alliance • Landowners • Natural Resources Conservation Service • Arkansas Game and Fish Commission • The Nature Conservancy • Local governments (cost share) • Local water suppliers (cost share) • US Army Corps of Engineers (ACOE)

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
Improved Construction Site Management & LID • Enforce minimum federal, state, and local requirements • Develop and administer compliance assistance program • Require silt fencing, detention ponds, and phased land disturbance • Educate on importance of implementing MS4 requirements for post-construction stormwater management • Identify communities, developers and contractors willing to use stormwater Best Management Practices • Conduct outreach to communities, developers and contractors • Develop site design standards, inspection protocols, and a channel protection/Low Impact Development Manual • Develop incentives for program participation • Advertise to participants • Work with suppliers of construction products/LID to provide discounts • Develop and administer compliance assistance/certification program for developers and contractors • Design and Implement Stormwater BMP Retrofits	• Local stormwater programs • Homebuilders Association • ADEQ • Local water suppliers • Local governments • ANRD – 319 Funds • Local stormwater impact fee on new development via local governments or stormwater utility • Stormwater impact fee on impervious area • Fines for noncompliance • Volunteer construction site monitoring program (e.g., Upper Chattahoochee Riverkeeper; KY Waterways Alliance) (technical assistance only)	• Lead: Local governments and MS4 permittees in designated urbanized areas and Beaver Watershed Alliance • ADEQ • University of Arkansas Division of Agriculture – Cooperative Extension Service • Northwest Arkansas Council

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
Note: *This Protection Strategy recommends going beyond minimum standards where feasible to have local enforcement in non-urbanized area where there is currently state jurisdiction*		
Pasture, Nutrient and Manure Management for agricultural lands • Identify agricultural areas and priority sites • Continue educational and outreach efforts to stress importance of Nutrient Management Plans and highlight environmental and economic benefits of conservation practices • Facilitate implementation of nutrient management plans and other agricultural BMPs to reduce nutrient and sediment loss • Build agricultural conservation practice capacity within the Alliance • Support partner efforts in updating the Arkansas P-Index to include weighting factors for Karst, Floodplains and Slope • Initiate agricultural landowner surveys to better understand conservation practices (CP) implementation inhibitions among landowners and develop strategies to increase engagement and participation.	• NRCS Initiatives and Funding Opportunities such as land conservation practices • ANRD – 319 Funds • Poultry/Cattle organizations and businesses • University of Arkansas Division of Agriculture – Cooperative Extension Service • Local water utilities • Arkansas Department of Environmental Quality • Sustainable Agriculture Research and Education	• Lead: Natural Resource Conservation Service & Conservation Districts – Soil and Water Districts • Beaver Watershed Alliance • University of Arkansas Division of Agriculture – Cooperative Extension Service • Arkansas Discovery Farms Program • National Center for Appropriate Technology
Agricultural Ponds • Identify Ag pond areas and prioritize sites (existing or new)	• NRCS Initiatives and Funding Opportunities such as land conservation practices	• Lead: Natural Resource Conservation Service & Beaver Watershed Alliance

Protection Strategy Component	**Potential Funding/Assistance**	**Responsible Group(s)**
• Assess ponds near unpaved roads or opportunity for ponds near unpaved roads • Conduct outreach landowners and land managers • Develop local vendor/contractors list for pond excavation • Develop pond retrofit program • Utilize ponds in innovative ways to reduce peak flows	• ANRD – 319 Funds • Poultry/Cattle organizations and businesses • University of Arkansas Division of Agriculture –Cooperative Extension Service • Local water utilities	
Component #3 Education and Outreach		
Coordinate with other Partnerships and Communities to build on existing education efforts	• Capacity-building and education/awareness grant programs	• Lead: Beaver Watershed Alliance
Educate communities, developers, and contractors on importance of implementing MS4 requirements for construction and post-construction stormwater management (see above)	• Local stormwater impact fee on new development	• Lead: Local governments and MS4 permittees in designated urbanized areas • University of Arkansas Division of Agriculture – Cooperative Extension Service • Beaver Watershed Alliance
Develop/build on local resources and materials to educate about: • Property and stream modification • Gravel mining • Onsite wastewater treatment • Floodplain development • Nutrient management • Streambank erosion • Riparian buffers • Riparian restoration	• ANRD – 319 Funds • University of Arkansas Dept of Agriculture –Extension Service • Local water suppliers • Local governments • Foundations	• Lead: Beaver Watershed Alliance • University of Arkansas Division of Agriculture – Cooperative Extension Service • Conservation groups • Landowners – help distribute • Local governments – technical assistance and distribution • Local water suppliers– technical assistance and distribution

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
• Other Land Conservation opportunities	• Grants.gov opportunities	
Continue educational efforts to stress implementation of farm Nutrient Management Plans and to highlight innovative practices	• NRCS Initiatives and Funding Opportunities such as land conservation practices • ANRD – 319 Funds • Poultry/Cattle organizations and businesses • University of Arkansas Dept of Agriculture • Local water utilities	• Lead: Natural Resource Conservation Service & Conservation Districts – Soil and Water Districts • Beaver Watershed Alliance • University of Arkansas Division of Agriculture –Cooperative Extension Service • University of Arkansas Discovery Farms Program
Develop Conservation Design guidelines and examples for new development in rural areas Ex) Smart Growth for Source Water Protection programming Revise local ordinances to allow conservation design as an alternative to traditional development	• ANRD – 319 Funds • University of Arkansas Dept of Agriculture –Extension Service • Local water suppliers • Local governments • Foundations • Grants.gov opportunities	• Lead: Beaver Watershed Alliance and local governments • NWA Regional Planning Commission • NWA Council • University of Arkansas Dept of Agriculture –Extension Service • University of Arkansas Architecture, Engineering, Design Centers • Conservation groups • Local governments – technical assistance and distribution • Local water suppliers– technical assistance
• Continue and enhance good lake management practices • Shoreline maintenance and erosion control • Buffer for nutrient sources	• Local water suppliers • US Army Corps of Engineers	• Lead: US Army Corps of Engineers • Beaver Watershed Alliance • Arkansas Game & Fish Commission

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
• Draw down lake elevation slowly to minimize impacts on water supply intakes		• University of Arkansas Dept of Agriculture –Extension Service "Lake Smart" programs
Component #4 Monitoring and Adaptive Management		
• Utilize Beaver Watershed Alliance Watershed Success Metrics Framework to monitor progress and assess gaps • Track progress through master database and report metrics on an annual basis • Examine and discuss new trends in water quality and to identify emerging issues on the watershed in order to evaluate and revise the Protection Strategy • Review/Update as needed the Beaver Lake Watershed Protection Strategy *Assume five-year adaptive management cycle	• Local water suppliers • ANRD • Foundations • Local governments • Conservation groups • US Army Corps of Engineers • Grants.gov opportunities	• Lead: Beaver Watershed Alliance
• Coordinate with local water quality groups to continue to assess monitoring and monitoring needs • Enhance long-term watershed and lake monitoring • Review current state, local, water suppliers and Arkansas Water Resources Center monitoring programs in context of Protection Strategy and corresponding assessment program to clarify gaps • Identify monitoring needed • Develop monitoring plan and estimated costs	• Local water suppliers • ADEQ • ANRD • US Geological Survey • Arkansas Water Resources Center • Foundations • Local governments • Conservation groups • US Army Corps of Engineers	• Lead: Beaver Watershed Alliance • ADEQ • Local water suppliers • Local governments • ANRD • US Geological Survey • Arkansas Water Resources Center • Conservation Groups • US Army Corps of Engineers

Protection Strategy Component	Potential Funding/Assistance	Responsible Group(s)
• Secure funding • • Implement monitoring program, which addresses five-year adaptive management cycle	• Grants.gov opportunities • NRCS Initiatives for instream/water ways and on farm monitoring programs	

Table 5-4. Beaver Lake Watershed Protection Strategy Implementation Timeline: Assuming five-year Adaptive Management cycle beginning May 2023 or at adoption of the updated Strategy.

Protection Strategy Component	Timeline
Component #1 Beaver Watershed Alliance	
Review/Update as needed the Beaver Lake Watershed Protection Strategy *Assume five-year adaptive management cycle	Initial Report – 2011 Update completed 2012, US EPA Accepted 2023 – Updated by RTI
Identify dedicated funding sources for operations and implementation of Strategy Components	May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Component #2 Conservation Practices	
Land Conservation: Conservation Easements & Conservation Agreements Identify Conservation Easements for Stream Buffers and Upland Areas Conduct screening and field evaluation of priority areas Conduct landowner outreach Secure funding sources Identify/secure stewardship organizations Develop stewardship plan Explore Transfer of Development Rights Program Explore Carbon Credit Program	Initial Phase July 2012-2016, 2017-2023 NWALT completed Strategic Land Conservation Plan, including a Watershed Conservation Priority Index (CPI), 2021 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Land Restoration Conduct screening and field evaluation of priority areas for riparian, pasture, forest, prairie, glade, wetlands, unpaved roads and urban greenspace restoration sites Conduct landowner outreach Secure funding sources Identify/secure stewardship organizations	Initial Phase July 2012-2016, 2017-2023 Conduct Screening: May 2023 – March 2024 Conduct Outreach, secure funding, identify stewardship orgs, develop plans: May 2023 - March 2027

Protection Strategy Component	Timeline
Develop stewardship plans	May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Unpaved Road Improvements (emphasizing retrofits including ditch hydroseeding, water bars, wing ditches, and stream crossing stabilization)	Initial Phase July 2012-2016, 2017-2023 Programming established through ANRD Continue efforts May 2023 - March 2027
River Restoration, Streambank Restoration, and Stream Stabilization Identify unstable streambanks and prioritize sites Conduct field evaluations Conduct landowner outreach Coordinate with US ACOE, ADEQ and other permitting agencies Coordinate with cities on trails and infrastructure near waterways Develop preliminary designs and cost estimates Secure needed permits Secure funding Secure stewardship organizations Final planning and design Develop stewardship plan Implement	Initial Phase July 2012-2016, 2017-2023 Environmental Assessment completed for West Fork White River Subwatershed analysis completed for all HUC12 basins PL-566 established for West Fork White River May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Low Water Crossings – Stream Barriers Identify instream barriers and prioritize sites Conduct field surveys and evaluations Conduct landowner outreach Coordinate with US ACOE, ADEQ and other permitting agencies Develop preliminary designs and cost estimates Secure needed permits Secure funding Implement	July 2012-March 2023 Arkansas Stream Heritage Partnership Developed Southeast Aquatic Resource Partnership (SARP) database developed May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Improved Construction Site Management Enforce minimum federal, state, and local requirements Develop and administer compliance assistance program Require silt fencing, detention ponds, and phased land disturbance Educate on importance of implementing MS4 requirements for post-construction stormwater management	Initial Phase July 2011 -2014 July 2011 – July 2013 August 2013– March 2023 Low Impact Development Manual Developed, UACDC Pilot projects installed to demonstrate LID May 2023 – March 2027 (Short Term, Mid Term, Long Term)

Protection Strategy Component	Timeline
Identify communities, developers and contractors willing to use stormwater Best Management Practices Conduct outreach to communities, developers and contractors Develop site design standards, inspection protocols, and a channel protection/Low Impact Development Manual Develop incentives for program participation Advertise to participants Work with suppliers of construction products/LID to provide discounts Develop and administer compliance assistance/certification program for developers and contractors Note: *This Protection Strategy recommends going beyond minimum standards where feasible to have local enforcement in non-urbanized area where there is currently state jurisdiction*	
Pasture, Nutrient and Manure Management for agricultural lands Identify agricultural areas and prioritize sites Conduct educational and outreach efforts to stress importance of Nutrient Management Plans and highlight environmental and economic benefits of conservation practices Facilitate implementation of nutrient management plans and other agricultural BMPs to reduce nutrient and sediment loss Build agricultural conservation practice capacity within the Alliance Support partner efforts to update the Arkansas P-Index to include weighting factors for Karst, Floodplains and Slope Conduct agricultural landowner survey to better understand CP implementation inhibitions among landowners and develop strategies to increase engagement and participation.	January 2012 – January 2017 Alliance joined NRCS State Technical Committee's to help support agricultural landowner needs February 2017 – March 2023 Alliance hired Agricultural Specialist LULC and demographic analysis to better match programming opportunities to landowner needs Alliance spearheaded NWQI to work with NRCS on landscape initiatives that targeted agricultural producers in Brush and Roberts Creek. May 2023 – March 2024 Refine LTEC and Modified Pond scenarios for agricultural lands and collaborate with partners to evaluate effectiveness Participate in landscape-scale initiatives such as the NRCS-RCPP that will implement NRCS agricultural land management practices Identify agricultural areas and prioritize sites

Protection Strategy Component	Timeline
	May 2023 – March 2027 (Short Term, Mid Term, Long Term) Increase NRCS-TSP certified in agricultural conservation practices Continue to develop, implement, and evaluate efficacy of innovative agricultural BMPs that optimize benefits for WQ in BLW Develop survey of agricultural landowners to identify and understand CP implementation inhibitions and develop a more inclusive strategy based on findings
Agricultural Ponds Identify Agricultural pond areas and prioritize sites (existing or new) Assess ponds near unpaved roads or opportunity for ponds near unpaved roads Conduct outreach to landowners and land managers Develop local vendor/contractors list for pond excavation Develop pond retrofit program Utilize ponds in innovative ways to reduce peak flows	February 2017 – March 2023 March 2023 – March 2024 Identify Agricultural pond areas and prioritize sites (existing or new) Assess ponds near unpaved roads or opportunity for ponds near unpaved roads Develop local vendor/contractors list for pond excavation March 2023 – June 2026 Develop pond retrofit program May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Component #3 Education and Outreach	
Coordinate with other Partnerships and Communities to build on existing education efforts	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Educate communities, developers, and contractors on importance of implementing MS4 requirements for construction and post-construction stormwater management (see above)	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Develop/build on local resources and materials to educate about: Property and stream modification Gravel mining Onsite wastewater treatment Floodplain development Nutrient management Streambank erosion Riparian buffers Riparian restoration Other Land Conservation opportunities	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)

Protection Strategy Component	**Timeline**
Continue educational efforts to stress implementation of farm Nutrient Management Plans and to highlight innovative practices	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Develop Conservation Design guidelines and examples for new development in rural areas Develop Smart Growth for Source Water Protection programming Revise local ordinances to allow conservation design as an alternative to traditional development	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Continue and enhance good lake management practices Shoreline maintenance and erosion control Buffer for nutrient sources Draw down lake elevation slowly to minimize impacts on water supply intakes	Initial Phases July 2012-2016, 2017-2023 May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Component #4 Monitoring and Adaptive Management	
Utilize Beaver Watershed Alliance Watershed Success Metrics Framework to monitor progress and assess gaps Track progress through master database and report metrics on an annual basis Examine and discuss new trends in water quality and to identify emerging issues on the watershed in order to evaluate and revise the Protection Strategy Review/Update as needed the Beaver Lake Watershed Protection Strategy *Assume five-year adaptive management cycle	Initial Phases March 2012-July 2014 2021 – Beaver Watershed Alliance master database developed 2022 – Watershed Success Metrics Framework developed and adopted by Alliance 2022 – Initiated BLWPS update with RTI May 2023 – March 2027 (Short Term, Mid Term, Long Term)
Coordinate with local water quality groups to continue to assess monitoring and monitoring needs Enhance long-term watershed and lake monitoring Review current state, local, water suppliers and Arkansas Water Resources Center monitoring programs in context of Protection Strategy and corresponding assessment program to clarify gaps Identify monitoring needed Develop monitoring plan and estimated costs	Initial Phase July 2012 – 2013 Completed March 2023 – March 2024 Identify monitoring gaps and needs as short-term goal May 2023 – March 2027 (Short Term, Mid Term, Long Term)

Protection Strategy Component	Timeline
Secure funding Implement monitoring program, which addresses five-year adaptive management cycle	

5.4 Adaptive Management

Because priorities can and will shift as new data are acquired and new water quality issues emerge, the Alliance and partnering organizations will utilize an adaptive management approach, where the goals of the organization and programming will be assessed every five years, approximately. Annual or biannual workplans and program agendas should be developed and evaluated organizationally. For example, the Beaver Watershed Alliance Watershed Success Metrics Framework should be utilized for each project or program implemented, the Alliance's staff and Board of Directors will determine success criteria in terms of community involvement and water quality improvement, and adjust programmatic goals and focus on the shorter terms. The Alliance has adopted the Strategy and is committed to ongoing review and updating of the document to ensure long-term relevancy. On a 5-year basis, the Alliance Technical Committee should reconvene to examine and discuss new trends in water quality and to identify emerging issues on the watershed to evaluate and revise the Strategy. Furthermore, as opportunity or need arises, the Strategy should be amended through notification and engagement of stakeholders and program partners. In summary, this is a living document that provides a guidance for the long-term protection of Beaver Lake and the restoration of the West, Middle, East Fork – White Rivers, along with Richland Creek, War Eagle Creek, Brush Creek, and Lakeside watershed areas. It is anticipated that the Alliance and its partners will review the key actions and timeline and revise them as new information is available, experience is gained, and success is achieved.

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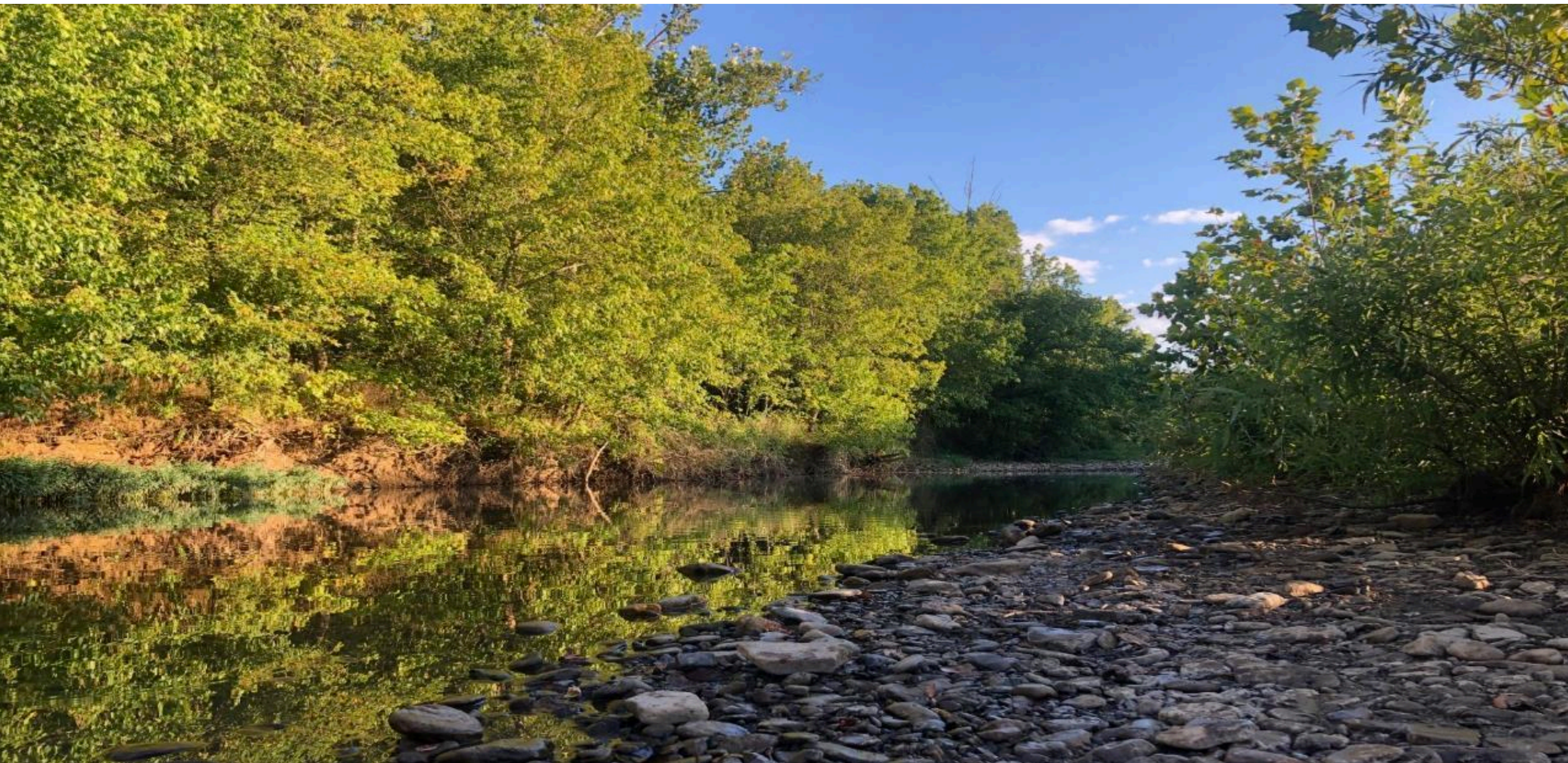

2. Appendix A: Conservation Practices Cost and Cost Effectiveness

Table A-1: Conservation Practices Unit Cost and Cost-effectiveness Summary Table[3]

Conservation Practice	20-Year Cost per Unit			Annualized Cost per unit			Cost per ton of Sediment Load reduced to Lake		
	Low	High	Median	Low	High	Median	Low	High	Median
Land Conservation Program -- Existing Pasture	$2,372.00	$3,558.00	$2,965.00	$118.60	$177.90	$148.25	$237.20	$355.80	$296.50
Land Conservation Program -- Existing Forest	$2,372.00	$3,558.00	$2,965.00	$118.60	$177.90	$148.25	$237.20	$355.80	$296.50
Improved Construction Site Management	$28,677.48	$38,046.88	$33,326.60	$1,433.87	$1,908.27	$1,671.07	$474.40	$593.00	$533.70
Buffer/Bank Restoration in Developed Areas Non-Lakefront (non-pasture land uses)	$222.97	$323.78	$273.97	$10.67	$16.60	$14.23	$1,660.40	$2,372.00	$2,016.20
Pasture Buffer/Bank Restoration Non-lakefront	$222.97	$323.78	$273.97	$10.67	$16.60	$14.23	$1,660.40	$2,490.60	$2,075.50
Alternative Water Source and Fencing	$972.52	$1,316.46	$1,150.42	$48.63	$66.42	$56.93	$1,897.60	$2,490.60	$2,194.10
Pasture Renovation	$568.09	$876.45	$722.27	$28.46	$43.88	$35.58	$355.80	$474.40	$415.10
Buffer Preservation, Non-lakefront (in developed areas)	$11.86	$35.58	$23.72	$0.59	$1.78	$1.19	$711.60	$2,253.40	$1,482.50
Unpaved Road Improvements	$20,055.26	$27,384.74	$23,720.00	$1,003.36	$1,369.83	$1,186.00	$830.20	$1,186.00	$1,008.10
Stormwater BMP Retrofits	$9,511.72	$33,255.44	$21,348.00	$475.59	$1,662.77	$1,069.77	$1,660.40	$5,811.40	$3,735.90
Additional Conservation Practice A	--	--	--	--	--	--	--	--	--
Total	--	--	--	--	--	--	$593.00	$948.80	$711.60

[3] These numbers were updated from the 2012 Strategy to account for inflation.

1. A.1 Pasture Renovation Economic Benefits Case Study (RTI International, 2022)

To illustrate the economic impacts of such conservation practices, one conservation practice, pasture renovation, and its associated value was explored in depth. A particular scenario, in which large county parcels (greater than 40 acres) with a majority NLCD Land Cover Type of Pasture that are within a 30-meter buffer of the NHDPlus Flowline were selected for “renovation” (Figure 4-4). These parcels were restored to a natural land cover type of oak savanna, which was represented with a new set of curve numbers as based on NRCS TR-55 (Cronshey, 1986): a woods-grass combination of 30% woods, good condition, an 70% meadow, good condition (RTI International, 2022) and then modeled for the Beaver Lake Watershed to assess the differences from the baseline condition. This scenario is referred to as the “Mitigation Scenario”.

A.1.1 Methods for Economic valuation

To assess the economic benefits of restoring riparian pasture lands across the watershed, monetary values were analyzed and estimated for two main benefit categories associated with water quality changes in Beaver Lake — lakeshore property values and drinking water treatment costs. These benefits were estimated by comparing the Future Land Use Scenario and the Mitigation Scenario. Because only future land use projections were available for 2050, it was assumed that the land use changes implied by the Future Land Use Scenario (compared to current conditions) would occur incrementally from 2020 to 2050. Similarly, it was assumed that the mitigation activities under the Mitigation Scenario would be implemented incrementally over the same period. Using this assumption, the value of water quality benefits that would accrue in 2050 was first estimated. Next, it was assumed that the annual benefits over the preceding 30 years would increase linearly, from zero in 2020 to the estimated value in 2050. The combined present value of these annual estimates (from a 2020 perspective) was then estimated, assuming that all future benefits are discounted at a 3% rate of discount.

To apply these watershed-level values at a smaller spatial scale (i.e., at a catchment level), average values per ton of sediment reduced across the watershed were also estimated. In other words, the benefit estimates for the watershed were divided by the change in sediment loads (in 2050) between the Mitigation Scenario and the Future Land Use Scenario. This average value can then be applied to value sediment reduction benefits from each individual catchment.

To estimate benefits for the two water quality benefit categories, a "benefit transfer" approach (Johnston, Rosenberger, Rolfe, & Brouwer, 2015) was developed and applied, which involves adapting and transferring results from existing economic valuation studies that have been conducted for locations and changes that are as similar as possible to the site of interest. This approach is widely used when, as in this case, benefit estimation studies are lacking for the specific location and environmental change being analyzed and when conducting original valuation research studies is not feasible.

A.1.2 Reduced Drinking Water Treatment Costs

One benefit of reducing sediment loads and improving water quality in Beaver Lake is that it should reduce the costs of treating drinking water by utilities that use the reservoir as a water source. Several studies have examined the relationship between treatment costs and source water quality, and there is strong evidence that higher levels of source water turbidity contribute to higher operation and maintenance costs at treatment facilities, particularly in the form of higher chemical and energy costs. A recent meta-analysis compiling and synthesizing results from nine studies in the United States (Price & Heberling, 2018) concluded that, on average, a 1% increase in source water turbidity leads to a 0.14% increase in annual chemical and energy costs. This average effect is referred to as the turbidity-cost elasticity.

To estimate these benefits, changes in treatment costs were focused on for the Beaver Water District (BWD). According to data from BWD, annual power and chemical costs have averaged $4.22 million per year over the last six years (2016 to 2021). This average was used to represent costs under the Baseline scenario. According to data provided by BWD, daily turbidity levels in the raw water at the BWD intake in these corresponding years have ranged from 1 to 660 NTU.

A polynomial relationship (EQ A-1; adjusted R^2 = 0.395) was developed between weekly average modeled sediment load (tons) to Beaver Lake from the major tributaries (White River, Richland Creek, Brush Creek, and War Eagle Creek) and the observed weekly average turbidity (NTU) in the raw water at the BWD intake (Figure A-1).

$$\text{Average Weekly Turbidity (NTU)} = -4E\text{-}13\,x^3 + 6E\text{-}08\,x^2 + 0.0012\,x + 3 \qquad \text{EQ A-1}$$

Where x = average weekly sediment load to Beaver Lake (tons)

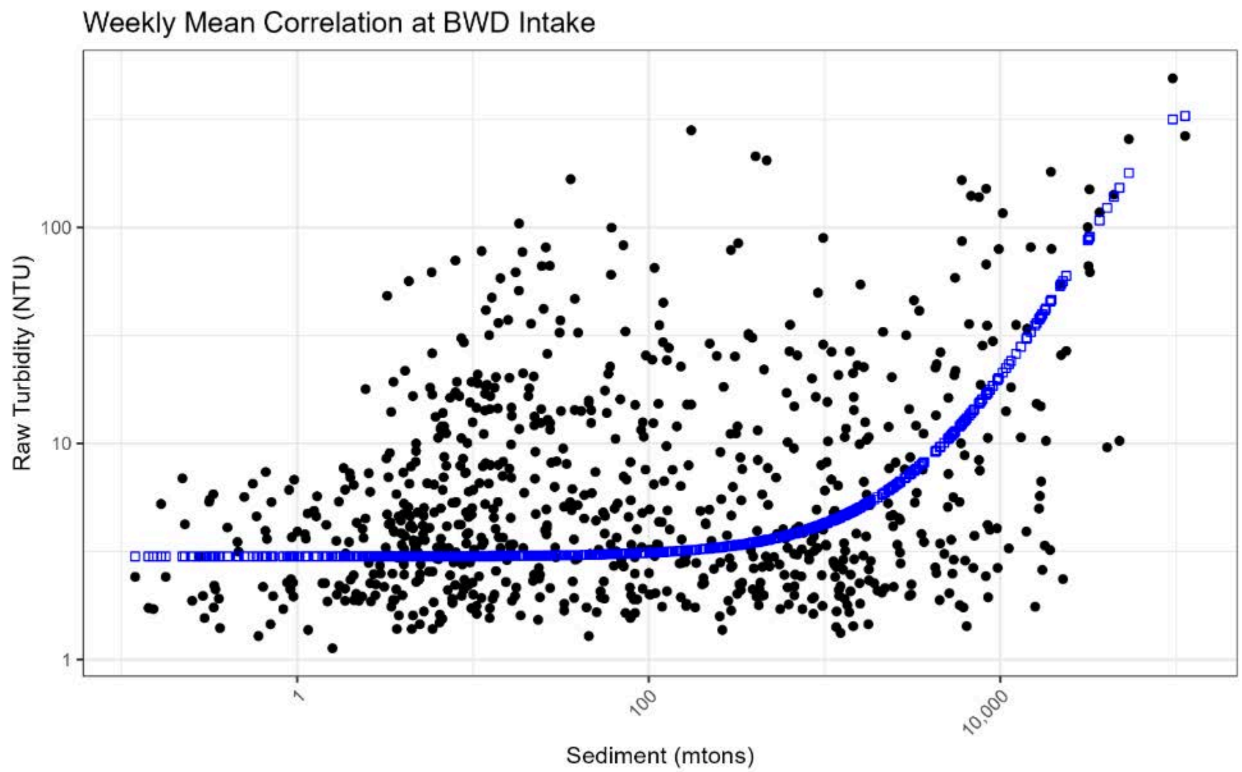

Figure A-1. Polynomial Relationship between the Weekly Average Sediment Load to Beaver Lake and the Weekly Average Measured Turbidity as Reported by the District for Raw Water at the Intake.

The increase in annual treatment costs between the Baseline and the Future Land Use Scenario due to increased sediment loadings and turbidity in the reservoir was first estimated. Under the Future Land Use Scenario, it is estimated that NTU will be 0.48% higher in 2050 than in the baseline, leading to an annual increase in treatment costs of $2,800. From that point, it is estimated that restoration activities under the Future Mitigation Land Use scenario will reduce NTU by 4.4%, resulting in a reduction in annual treatment cost in 2050 of $26,000.

Because the reduction in sediment loads in 2050 for the Future Mitigation Land Use scenario is estimated to be 144,506 tons (compared to the Future Land Use scenario), this implies that the average reduction in water treatment cost increment per ton of sediment reduced is \$0.18/ton for each year the mitigation measure is in place.

If we assume that decreases in annual water treatment costs grow incrementally from \$0 in 2020 to \$26,000 in 2050 as restoration activities are gradually implemented under the Future Mitigation Land Use scenario, this implies that the present value (in 2020) of cost reductions due to reduced turbidity under this scenario is roughly \$78,300.

A.1.3 Lakeshore Property Values

Residents who live along the lakeshore will also benefit from measures to protect and improve water quality in Beaver Lake. To estimate these benefits, results from an existing property value analysis by (Walsh, Milon, & Scrogin, 2011) were used. Although many empirical studies have analyzed and estimated how changes in water quality affect nearby property values, relatively few have focused on reservoir or lake water quality in the southeastern United States. The Walsh et al. study is one exception. It analyzed the effects of changes in water clarity (measured by Secchi depth) on lakefront properties in Orange County, Florida over the period 1996–2004. In summary, it was found that, at the larger lakes (over 1,000 acres) in their sample, each 1 m increase in Secchi depth increased lakefront property values by an average of 4.3%. For this analysis, it was assumed that changes in water clarity in Beaver Lake will have the same magnitude effect on lakeshore properties.

As a first step, a GIS analysis was conducted using parcel-level tax assessment data to identify the nearest residential properties within 65 meters from the Beaver Lake shoreline and to determine the baseline total value of these properties (Figure A-2). Based on this analysis. 3,970 properties were identified with an average value of \$252,081 and a combined value of \$1 billion.

Next, the extent to which changes in water quality by 2050 associated with the Future Land Use scenario (compared to baseline) would affect the value of these properties was estimated. Based on monitored data from 2006 to 2015 (Rich, 2018), water clarity across the whole lake, as measured by Secchi depth, has averaged 2.31 m. A regression analysis of the relationship (Adjusted R^2 = 0.74) between annual Secchi depth for the lake and annual sediment inflow loads from 2006 to 2015 (Figure A-3) shows that sediment loads a have a strong negative effect on water clarity.

$$\text{Whole Lake Annual Average Secchi Depth (m)} = 2.69 - 7.70 \times 10^{-7} \times \text{Annual Sediment Load (tons)} \quad \text{EQ 8-2}$$

This estimated regression relationship is applied to estimate how future increases in loads due land development will affect annuals Secchi depth. For the Future Land Use scenario, it is estimated that Secchi depth will increase only slightly by 0.0007 m compared to baseline in 2050. The projected land use changes throughout the watershed ultimately balance out with increases in some subwatersheds and decreases in others resulting in little change in the annual average sediment load and, therefore, little change in whole lake Secchi depth. However, under the Mitigation Future Land Use scenario, annual average Secchi depth increases by 0.12 m, which results in a 0.5% increase in lakefront property values. Overall, there is potential to increase the average property value by $1,300 and add approximately $5.2 million to combined property values around the lake by restoring the identified riparian pasture lands within the watershed (Figure 4-4).

One further note is that in addition to providing a means to deriving economic values, the established correlation, which included the major storm events of 2008, 2009, 2011, and 2015, further confirmed the peak sediment load impacts simulated by the model.

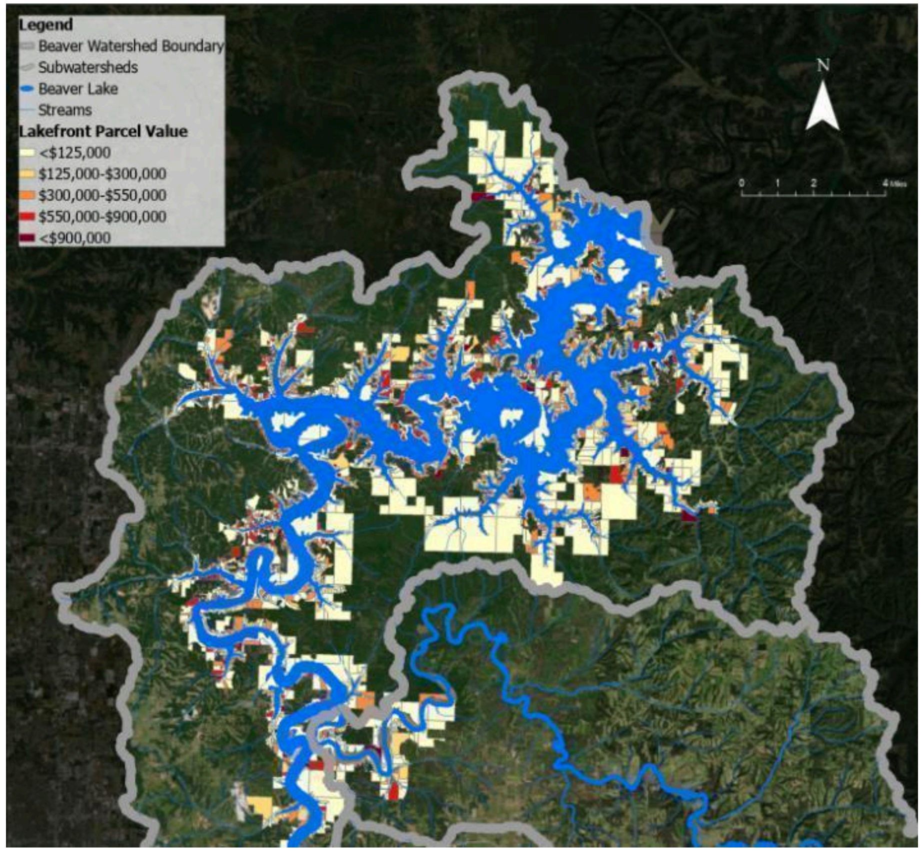

Figure A-2. Lakefront Properties GIS Analysis for Beaver Lake.

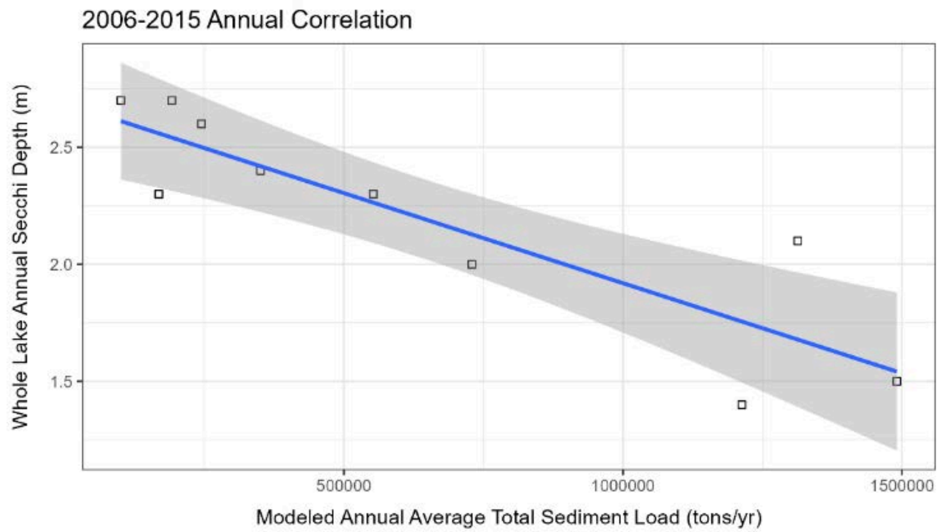

Figure A-3. Relationship between Annual Average Whole Lake Secchi Depth and Annual Sediment Load to Beaver Lake.

Because the reduction in sediment loads in 2050 for the Future Mitigation Land Use scenario is estimated to be 144,506 tons (compared to the Future Land Use scenario), this implies that the average lakeshore property value increment per ton of sediment reduced is $35.73/ton/yr.

If we assume that property values increase incrementally from 2020 to 2050 as restoration activities are gradually implemented under the Future Mitigation Land Use scenario, this implies that the present value (in 2020) of property value growth due to improved lake water clarity under this scenario is roughly $2.5 million.

A.1.4 Application of Economic Benefits

As the economic benefits have been calculated per ton of sediment reduced, the local catchment reduction in sediment due to mitigation can be calculated and used to determine the total annual benefits in terms of drinking water treatment reduced costs and increased lakeshore property values if all the target mitigation area within the catchment is addressed. To allow flexibility in selection of the mitigation area, it can be assumed that each mitigated acre of land produces the same reduction in sediment within a catchment. Therefore, a mass of sediment reduced per acre of land rate can be determined for each catchment. With this rate, a selected number of acres out of the total targeted mitigation area can be used to calculate the total annual benefits. These rates are depicted in Figure A-4.

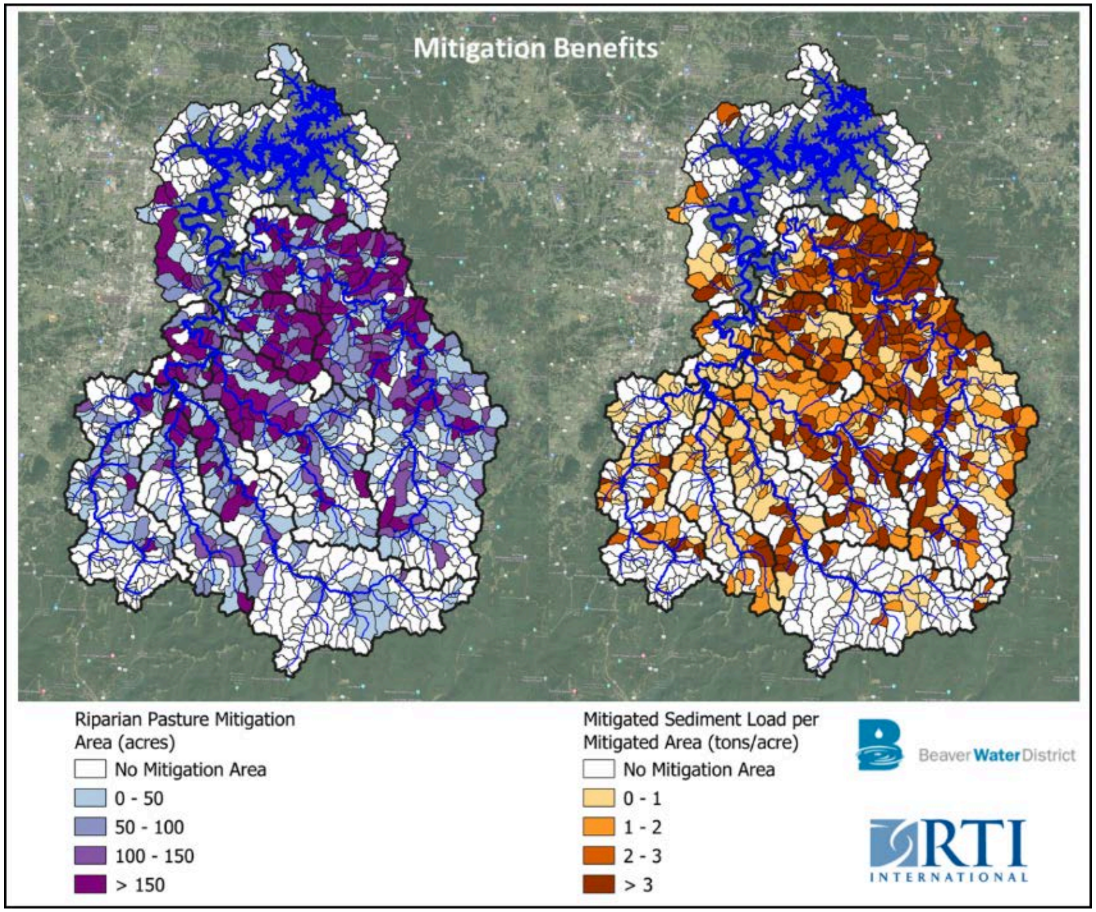

Figure A-4. Mitigation Area and Sediment Reduction Benefits for Use in Calculating Economic Benefit Values for the Beaver Lake Watershed.

3. Appendix B: WCRC Unpaved Road Maps and Priorities

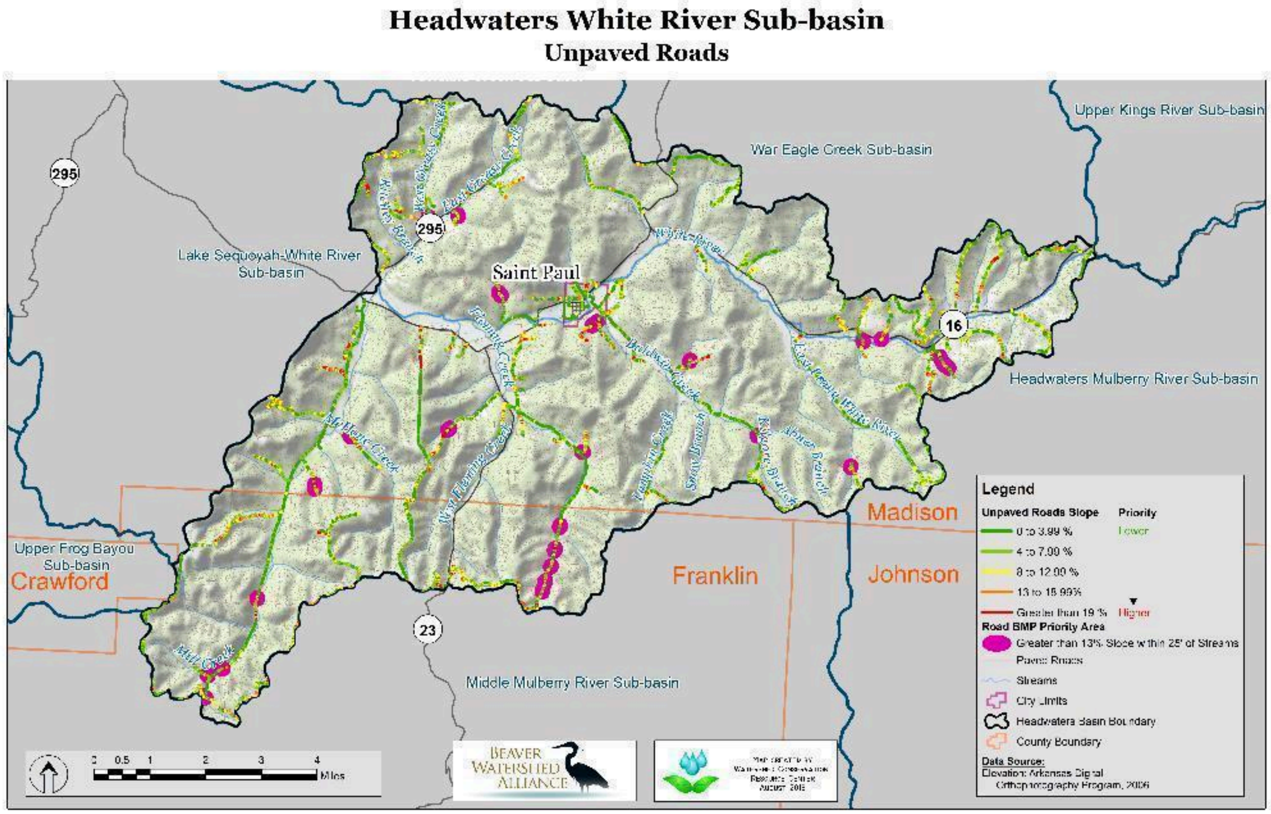

Figure B-1. Map of Unpaved Roads and Priorities for BMP Implementation in the Headwaters White River Subwatershed within the Beaver Lake Watershed (Provided by the Watershed Conservation Resource Center, 2023).

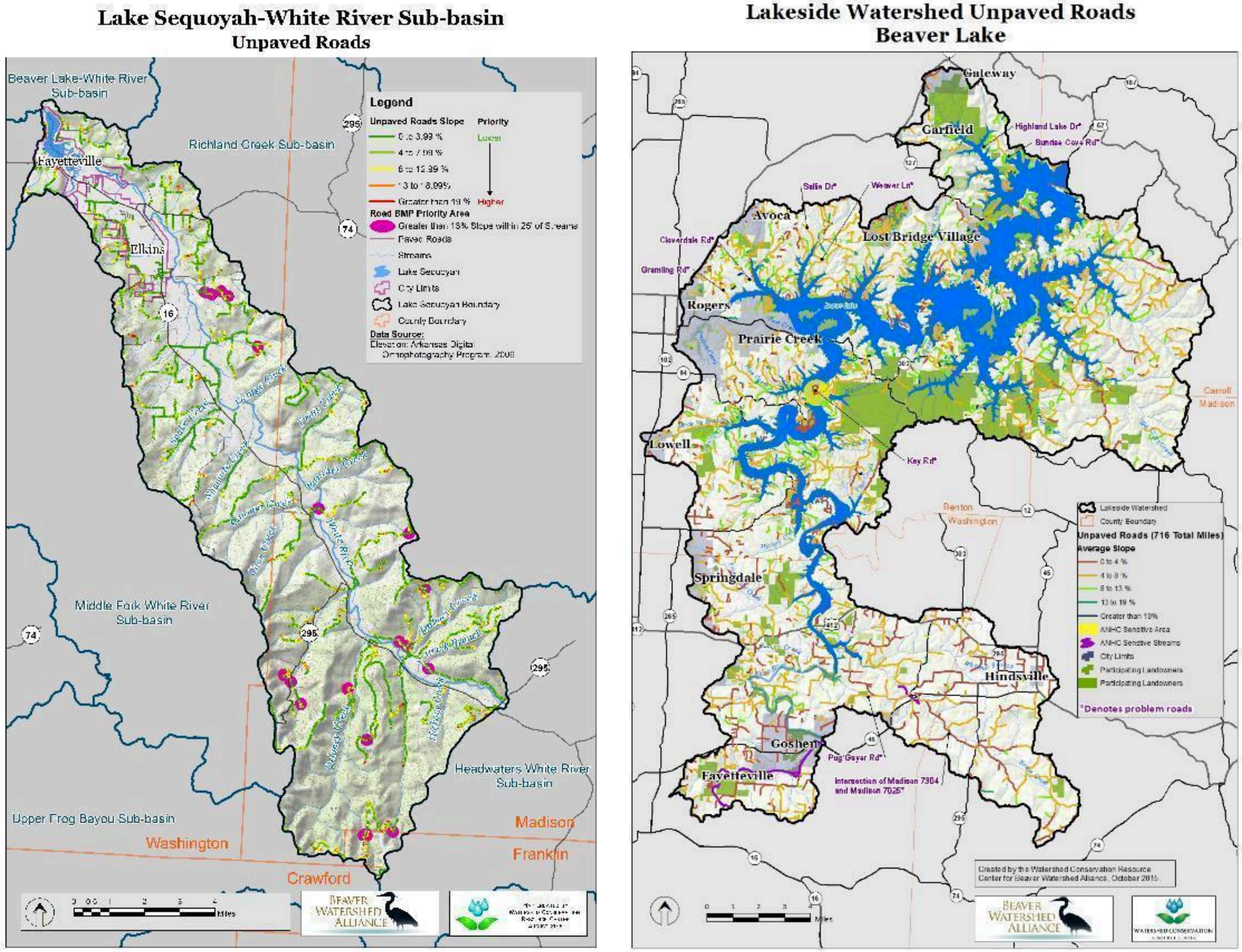

Figure B-2. Map of Unpaved Roads and Priorities for BMP Implementation in the Lake Sequoyah-White River Subwatershed (left) and Lakeside Subwatershed (right) within the Beaver Lake Watershed (Provided by the Watershed Conservation Resource Center, 2023).

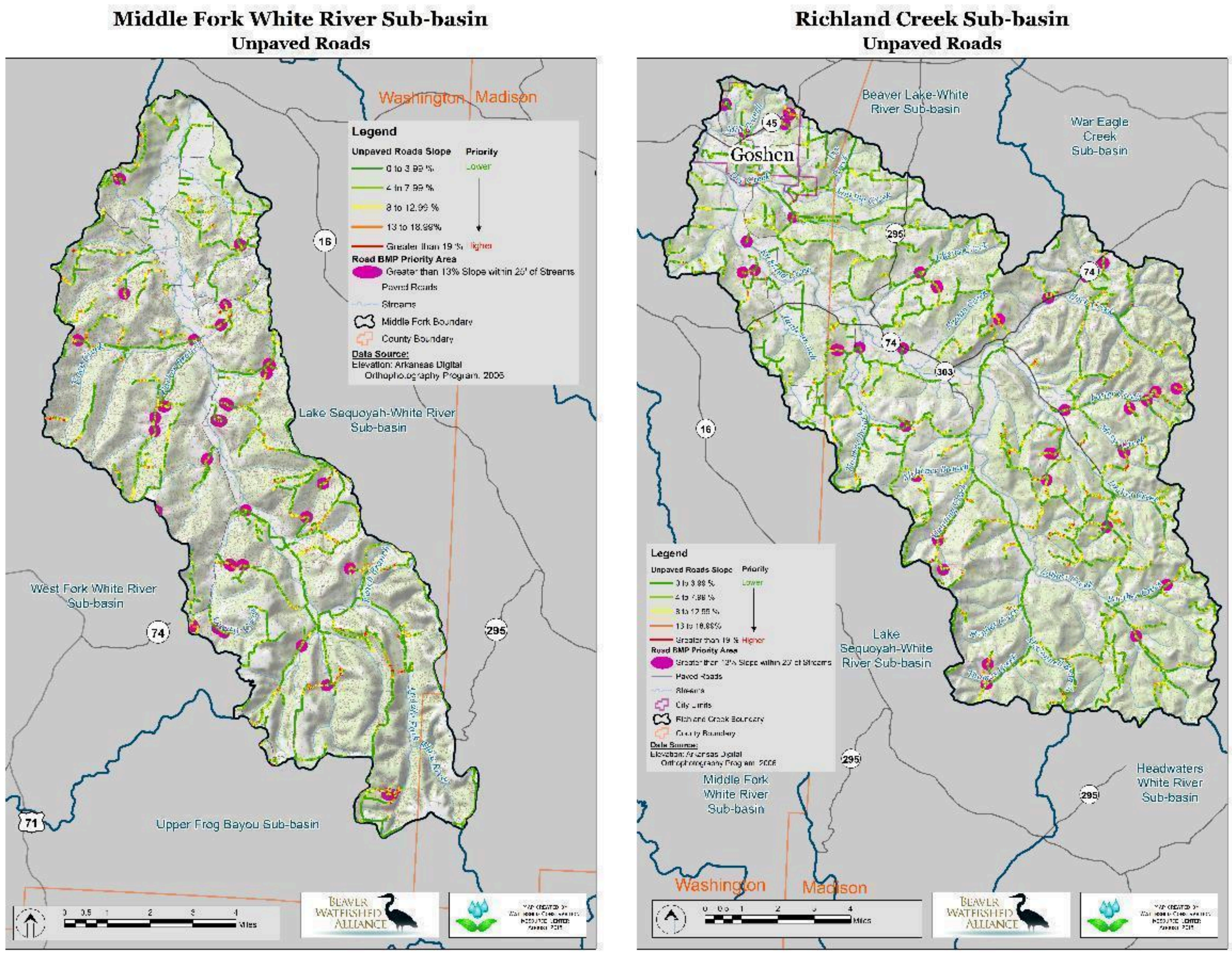

Figure B-3. Map of Unpaved Roads and Priorities for BMP Implementation in the Middle Fork White River Subwatershed (left) and Richland Creek Subwatershed (right) within the Beaver Lake Watershed (Provided by Watershed Conservation Resource Center, 2023).

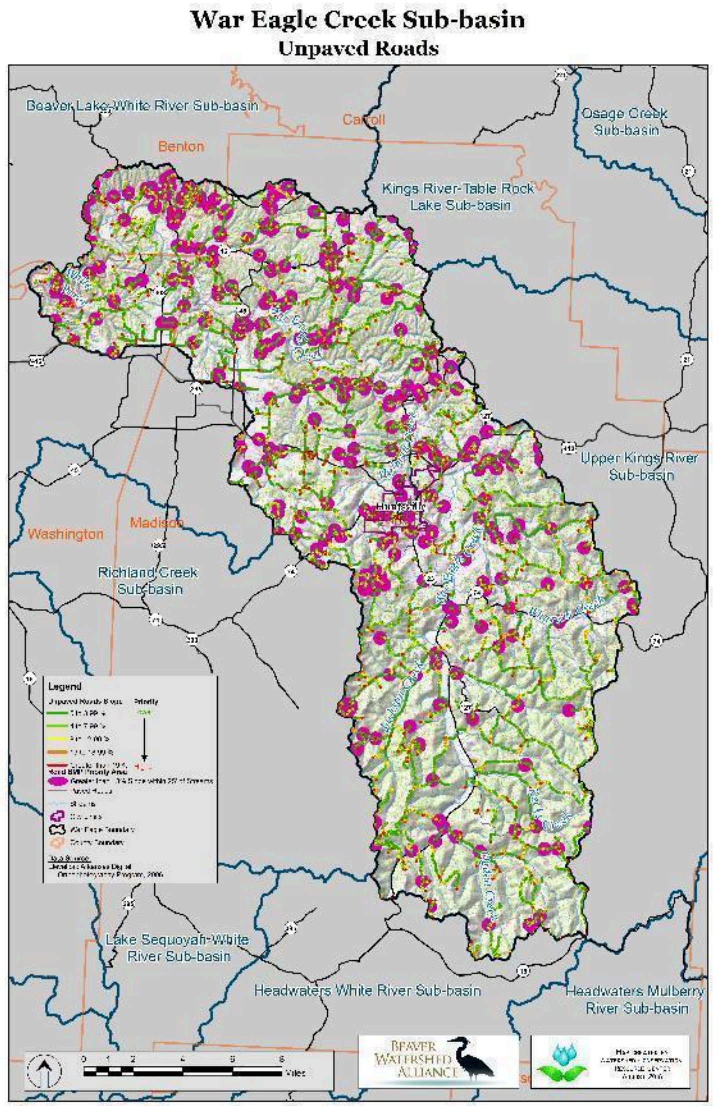

Figure B-4. Map of Unpaved Roads and Priorities for BMP Implementation in the War Eagle Creek Subwatershed within the Beaver Lake Watershed (Provided by the Watershed Conservation Resource Center, 2023).

4. Appendix C: Correlation of Beaver Lake Watershed Protection Strategy Components to EPA 9 Required Elements for Watershed Plans under Section 319 of the Federal Clean Water Act (U.S. EPA, 2008)

Table C-1. Correlation of Beaver Lake Watershed Protection Strategy Components to EPA 9 Required Elements for Watershed Plans under Section 319 of the Federal Clean Water Act

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA's		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
a) Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).	3-12 46-83 93-96 137-146	**Section 1.1** Why are These Protection Measures Needed **Section 2.2:** Existing and Future Loads to the Lake **Section 2.4** Priority Watershed Issues **ENVIRONMENTAL GOALS**	**Section 1.1.** provide historical water quality context. **Section 2.2** discusses the existing and future loads to the Lake, including a discussion of the various load sources considered and a discussion of the modeling. **Section 2.4** provides context to the list of impaired waters. This section defines environmental goals and monitoring strategy.	ADEQ 303D Lists Conservation Assessment of Beaver Lake Watershed (RTI International, 2022) Grantz and Haggard 2023
b) An estimate of the load reductions expected from management measures.	147	**Section 4.3:** Management Measures, Costs, and Load Reduction Estimates	**Table 4-7** includes estimated load reduction efficiencies achieved through management measures used within the watershed.	Conservation Assessment of Beaver Lake Watershed (RTI International, 2022)

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA's		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
c) A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element b, and a description of the critical areas in which those measures will be needed to implement this plan.	137-146 110-132	**ENVIORNMENTAL GOALS** **Section 4.2.2:** Component #2 – Conservation Practices	This section defines environmental goals and monitoring strategy. **Section 4.2.2** includes descriptions of nonpoint source management measures, termed conservation practices that improve load reductions.	
d) Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	109-132 187-194 153-181	**Section 4.2:** Four Components of Updated Protection Strategy **Appendix A:** Conservation practices Cost and Cost Effectiveness **Section 5:** Proposed Beaver Lake Watershed Protection Strategy Summary	**Section 4.2:** Four Components of Updated Protection Strategy and Appendix A for cost information; See **Section 5** for Beaver Lake Watershed Protection Implementation Summary for potential sources of funding and assistance.	
e) An information and education component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	110-132 133-134	**Section 4.2.2:** Component #2 – Conservation Practices **Section 4.2.3:** #4 Education and Outreach Program	See **Section 4.2.2** #2 Conservation Practices, and **Section 4.2.3** #3 Education and Outreach Program for training, education, and outreach components.	
f) Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	168-180 168	**Section 5.3:** Implementation Timeline	See **Section 5.3** and associated table for Implementation Timeline.	

EPA 319 Required Element	Quick Reference Listing: Strategy Content Correlation to EPA's		Strategy Section Description	ADDITIONAL REFERENCE DOCUMENT(S)
	PAGES(S)	*SECTION/TITLE*		
g) A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.		**Table 5-4.** Beaver Lake Watershed Protection Strategy Implementation Timeline		
h) A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.	83-92 93-96 137-146	**Section 2.3:** Water Quality Standards **Section 2.4** Priority Watershed Issues **ENVIRONMENTAL GOALS**	**Section 2.3:** Water Quality Standards and criteria to measure progress. **Section 2.4:** provides context to the list of impaired waters. This section defines environmental goals and monitoring strategy.	
i) A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under element h.	135-145	**Section 4.2.4:** Component #4 Monitoring and Adaptive Management	**Section 4.2.4:** Component #4 Monitoring and Adaptive Management	